Open|SpeedShop Reference Guide

November 22, 2016
Version 2.3.0

Contributions from Krell Institute, LANL, LLNL, SNL

Table of Contents

About this Manual

This reference guide provides basic Open|SpeedShop (O|SS) usage information.

This manual intends to give users an understanding of the general experiments available in O|SS that can be used to analyze application code. There is extensive information provided about how to use the O|SS experiments and how to view the performance information in informative ways. Hopefully this will allow users to start optimizing and analyzing the performance of application code.

O|SS is a community effort by The Krell Institute with current direct funding from the Department of Energy's National Nuclear Security Administration (DOE NNSA). It builds on a broad list of community provided infrastructures, notably the Paradyn Project's Dyninst API and MRNet (Multicast Reduction Network) from the University of Wisconsin at Madison, the Libmonitor profiling tool, and the Performance Application Programming Interface (PAPI) from the University of Tennessee at Knoxville. O|SS is an open source multi-platform Linux performance tool which is targeted to support performance analysis of applications running on both single node and large scale Intel, AMD, ARM, Intel Phi, PPC, GPU processor based systems and on Blue Gene and Cray platforms.

O|SS is explicitly designed with usability in mind and is for application developers and computer scientists. The base functionality includes:

- Overview Program Counter Sampling Experiment
- Support for Call Stack Analysis
- Access to the Hardware Performance Counters
- MPI Profiling and Tracing
- I/O Profiling and Tracing
- Memory Analysis Tracing
- POSIX Thread Function Tracing
- NVIDIA CUDA Event Tracing
- OpenMP Profiling and Analysis

In addition, O|SS is designed to be modular and extensible. It supports several levels of plug-ins, which allow users to add their own performance experiments.

O|SS development is hosted by the Krell Institute. The infrastructure and base components of O|SS are released as open source code primarily under LGPL. Highlights include:

- Comprehensive performance analysis for sequential, multithreaded, and MPI applications
- No need to recompile the user's application.
- Supports both first analysis steps as well as deeper analysis options for performance experts

- Easy to use GUI and fully scriptable through a command line interface and Python
- Supports Linux Systems and Clusters with Intel and AMD processors
- Extensible through new performance analysis plugins ensuring consistent look and feel
- In production use on all major cluster platforms at LANL, LLNL, and SNL and other sites around the world

Features include:

- Four user interface options: batch, command line interface, graphical user interface and Python scripting API.
- Supports multi-platform single system image (SSI) and traditional clusters.
- Scales to large numbers of processes, threads, and ranks.
- View performance data using multiple customizable views.
- Save and restore performance experiment data and symbol information for post experiment performance analysis.
- View performance data for all of application's lifetime or smaller time slices.
- Compare performance results between processes, threads, or ranks between a previous experiment and current experiment.
- Interactive CLI help facility, which lists the CLI commands, syntax, and typical usage.
- Option to automatically group like-performing processes, threads, or ranks.

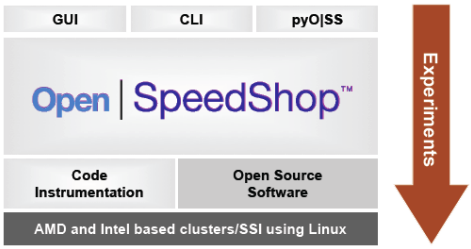
1 Introduction to Open|SpeedShop

Open|SpeedShop (O|SS) is an open source performance analysis tool framework. It provides the most common performance analysis steps all in one tool using a common shared interface. It is easily extendable by writing plugins to collect and display performance data. It also comes with built in experiments to gather and display several types of performance information.

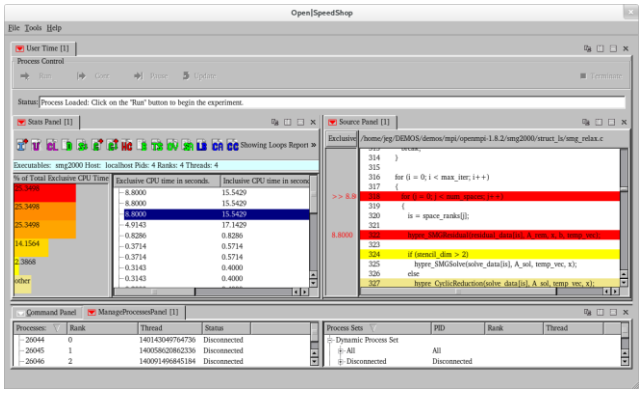
O|SS provides several flexible and easy ways to interact with it. There is a GUI to launch and examine experiments, a command line interface that provides the same access as the GUI, as well as python scripts. There are also convenience scripts that allow you to run standalone experiments on applications and examine the results at a later time.

The existing experiments for O|SS all work on unmodified application binaries. O|SS has been tested on a variety of Linux clusters and supports Cray and Blue Gene systems.

1.1 Basic Concepts, Interface, Workflow



O|SS has three ways for the user to examine the results of a performance test, called experiments, a GUI, a command line interface or through python libraries. The user can also start experiments by using those three options or by an additional method of the command line launched convenience scripts. For example, to launch one of the convenience scripts for the pcsamp experiment (Program Counter Sampling) the user executes the command osspcsamp "<application>", where <application> is the executable under study along with any arguments. The convenience scripts will then create a database for the results of that experiment.



The user can examine any database in the GUI with the command:

```
openss –f <db file>
```

The GUI will provide some simple graphics to help you understand the results and will relate the data back to the source code when possible.

1.1.1 Common Terminology

Technical terms can have multiple and/or context sensitive meanings, therefore this section attempts to explain and clarify the meanings of the terms used in this document, especially with respect to the O|SS tools.

Experiment: A set of collectors and executable or executables bound together to generate performance information that can be viewed in human readable form.

Focused Experiment: The current experiment commands operate on. The user may run or view multiple experiments simultaneously and unless a particular experiment is specified directly, the focused experiment will be used. Experiments are given an enumeration, called an experiment id, for identification.

Component(s): A component is a somewhat self-contained code section of the O|SS performance tool. This section of code does a set of specific related tasks for the tool. For example, the GUI component does all the tasks related to displaying O|SS wizards, experiment creation, and results using a graphical user interface. The CLI component does similar functions but uses the interactive command line delivery method.

Collector: The portion of the tool containing logic that is responsible for the gathering of the performance metric. A collector is a portion of the code that is included in the experiment plugin.

Metric: The measurement, which the collector/experiment is gathering. A metric could be a time, an occurrence counter, or other entity, which reflects in some way on the application's performance and is gathered by a performance experiment at application runtime directly by the collector.

Offline: offline is the O|SS default mode of operation. It is a link override mechanism that allows for gathering performance data using libmonitor to link O|SS performance data gathering software components into the user application. For this mode of operation, the application must be run from start up to completion. The performance results may be viewed after the application terminates normally.

Param: Each collector allows the user to set certain values that control the way a collector behaves. The parameter or **param** may cause the collector to perform various operations at certain time intervals or it may cause a collector to measure certain types of data. Although O|SS provides a standard way to set a parameter, it is up to the individual collector to decide what to do with that information. Detailed documentation about the available parameters is part of the collector's documentation.

Framework: The set of API functions that allows the user interface to manage the creation and viewing of performance experiments. It is the interface between the user interface and the cluster support and dynamic instrumentation components.

Plugin: A portion (library) of the performance tool that can be loaded and

included in the tool at tool start-up time. Development of the plugin uses a tool specific interface (API) so that the plugin, and the tool it is to be included in, know how to interact with each other. Plugins are normally placed in a specific directory so that the tool knows where to find the plugins.

Target: This is the application or part of the application that O|SS is running the experiment on. In order to fine tune what is being targeted, O|SS gives target options that describes file names, host names, thread identifiers, rank identifiers and process identifiers.

1.1.2 Concept of an Experiment

O|SS uses the concept of an experiment to describe the gathering of performance measurement data for a particular performance area of interest. Experiments consist of the performance data collector responsible for the gathering of the measurements associated with the performance area of interest. The collector, which is a small dynamic or static object library, also contains functions that can interpret the gathered measurements, i.e., performance data, into a human understandable form. The experiment definition also includes the application being examined and how often the data will be gathered (the sampling rate). The application's symbol information is saved into the experiment output file so that performance reports can be generated from the performance data file alone. The application, itself, need not be present to view the performance data at a later time.

1.2 Performance Experiments Overview

O|SS refers to the different performance measurements as experiments. Each experiment can measure and analyze different aspects of the code's performance. The experiment type, or type of data gathered, is chosen by the user. Any experiment can be applied to any application, with the exception of MPI specific experiments being applied to non-MPI applications.

Each experiment consists of collectors and views. The collectors define specific performance data sources, for example, program counter samples, call stack samples, hardware counters or tracing of library routines. Views specify how the performance data is aggregated and presented to the user. It is possible to implement multiple collectors per experiment.

1.2.1 Individual Experiment Descriptions

The following table provides a quick overview of the different experiment types that come with O|SS.

Experiment	Experiment Description
pcsamp	Periodic sampling the program counters gives a low-overhead view of where the time is being spent in the user application.
usertime	Periodic sampling the call path allows the user to view inclusive and exclusive time spent in application routines. It also allows the user to see which routines called which routines. Several views are available, including the "hot" path.
hwc	Hardware events (including clock cycles, graduated instructions, instruction and data cache and TLB misses, floating-point operations) are counted at the machine instruction, source line and function levels.
hwcsamp	Similar to hwc, except that sampling is based on time, not PAPI event overflows. Up to six events may be sampled during the same experiment.
hwctime	Similar to hwc, except that call path sampling is also included.
io	Accumulated wall-clock durations of input/output (I/O) system calls: read, readv, write, writev, open, close, dup, pipe, creat and others. Show call paths for each unique I/O call path.
iop	Lightweight I/O profiling: Accumulated wall-clock durations of I/O system calls: read, readv, write, writev, open, close, dup, pipe, creat and others, but individual call information is not recorded.
iot	Similar to io, except that more information is gathered, such as bytes moved, file names, etc.
mpi	Captures the time spent in and the number of times each MPI function is called. Show call paths for each MPI unique call path.
mpip	Lightweight MPI profiling: Captures the time spent in and the number of times each MPI function is called. Show call paths for each MPI unique call path, but individual call information is not recorded.
mpit	Records each MPI function call event with specific data for display using a GUI or a command line interface (CLI). Trace format option displays the data for each call, showing its start and end times.
mem**	Tracks potential memory allocation call that is not later destroyed (leak). Records any memory allocation event that set a new high-water of allocated memory current thread or process. Creates an event for each unique call path to a traced memory call and records the total number of times this call path was followed, the max allocation size, the min allocation size, and the total allocation, the total time spent in the call path, and the start time for the first call.
pthreads	Captures the time spent in and the number of times each POSIX thread function is called. Show call paths for each POSIX thread function's unique call path
omptp	Report task idle, barrier, and barrier wait times per OpenMP thread and attribute those times to the OpenMP parallel regions.

cuda*	Captures the NVIDIA CUDA events that occur during the application execution and report times spent for each event, along with the arguments for each event, in an event-by-event trace.

* Not available in O|SS using the offline mode of operation, at this time.
**If run in offline mode, the memory experiment performance data is not reduced in the manner that it is in the default mode of operation because the filters are not called during offline mode of operation.

1.2.3 Overview of the Sampling Experiments

Program counter sampling (pcsamp) experiment, call path profiling (usertime) experiment, and the three hardware counter experiments (hwc, hwctime, hwcsamp) all use a form of sampling based performance information gathering techniques.

Program Counter Sampling (pcsamp) is used to record the Program Counter (PC) in the user application being monitored by interrupting the application at a user defined time interval, with the default being 100 times a second. This experiment provides a low overhead overview of the time distribution for the application. Its lightweight overview provides a good first step for analyzing the performance of an application.

The Call Path Profiling (usertime experiment) gathers both the PC sampling information and also records call stacks for each sample. This allows the later display of the call path information about the application as well as inclusive and exclusive timing data (see section 4.2). This experiment is used to find hot call paths (call paths that take the most time) and see who is calling whom.

The Hardware Counter experiments (hwc, hwctime, hwcsamp) access data like Cache and TLB misses. The experiments hwc and hwctime, sample a hardware counter events, based on an event threshold. The default event is PAPI_TOT_CYC overflows. Please see chapter 5 for more information on PAPI and hardware counter related experiments. Instead using a threshold, the hwcsamp experiment samples up to six events based on a sample time, similar to the usertime and pcsamp experiments. The hwcsamp experiment default events are PAPI_FP_OPS and PAPI_TOT_CYC.

1.2.4 Overview of the Tracing Experiments

The Input/Output tracing and profiling experiments (io, iot, iop), MPI Tracing Experiments (mpi, mpip, mpit), Memory tracing (mem), and the POSIX thread tracing (pthread) all use a form of tracing or wrapping of the function names to record performance information. Tracing experiments do not use timers or thresholds to interrupt the application. Instead they intercept the function calls of interest by using a wrapper function that records timing and function argument

information, calls the original function, and then records this information for later viewing with O|SS's user interface tools.

The Input/Output tracing experiments (io, iot) record invocation of all POSIX I/O events. They both provide aggregated and individual timings and, in addition, the iot experiment also provides argument information for each call. To obtain a more lightweight overview of application I/O usage, use the I/O profiling experiment. The lightweight I/O experiment (iop) records the invocation of all POSIX I/O events, accumulating the information, but does not save individual call information like the io and iot experiments do. That allows the iop experiment database to be smaller and makes the iop experiment faster than the io and iot experiments.

The memory tracing experiment (mem) records invocation of all tracked memory function calls, also referred to as events. The mem experiment provides aggregated and individual timings and also provides argument information for each call.

The MPI Tracing Experiments (mpi, mpit) record invocation of all MPI routines as well as aggregated and individual timings. The mpit experiment provides argument information for each call. To obtain a more lightweight overview of application MPI usage, use the MPI profiling experiment (mpip). The lightweight MPI experiment (mpip) records the invocation of all MPI function call events, accumulating the information, but does not save individual call information like the mpi and mpit experiments do. That allows the mpip experiment database to be smaller and makes the mpip experiment faster than the mpi and mpit experiments.

The POSIX thread tracing experiment (pthreads) records invocation of all tracked POSIX thread related function calls, also referred to as events. The pthreads experiment provides aggregated and individual timings and also provides argument information for each call.

1.2.5 Parallel Experiment Support

O|SS supports MPI and threaded codes; it has been tested with a variety of MPI implementations. The thread support is based on POSIX threads and OpenMP is supported in a number of ways including via POSIX threads, OpenMP wait time augmentation of the sampling experiment and through the omptp OpenMP profiling experiment.

Any O|SS experiment can be applied to any parallel application. This means you can run the program counter sampling experiment on a non-parallel application as well as a MPI or threaded application. The experiment data collectors are automatically applied to all tasks/threads. The default views aggregate (sum the performance data) across all tasks/threads but data from individual tasks/threads are available. The MPI calls are wrapped, and MPI function elapsed time and parameter information is displayed.

1.3 Running an O|SS Experiment

First think about what parameters you want to measure then choose the appropriate experiment to run. You may want to start by running the pcsamp experiment since it is a lightweight experiment and will give an overview of the timing for the entire application.

Once you have selected the experiment to run you can launch it with either the wizard in the GUI or by using the command line convenience scripts. For example, say you have decided to run the pcsamp experiment on the Semi coarsening Multigrid Solver MPI application smg2000. On the command line you would issue the command:

```
> osspcsamp "mpirun –np 256 smg2000 –n 60 60 60"
```

Where "mpirun –np 256 smg2000 –n 60 60 60" is a typical MPI application launching command you would normally use to launch the smg2000 application. mpirun, a MPI driver script or executable, is used to launch smg2000 on 256 processors with "-n 60 60 60" is passed as an argument to smg2000.

An example of a MPI smg2000 pcsamp experiment run from a SLURM based system using "srun" as the MPI driver, along with the application and experiment output follows below:

```
> osspcsamp "srun -n 256 ./smg2000 -n 60 60 60"
```

```
[openss]: pcsamp experiment using the pcsamp experiment default sampling rate: "100".
[openss]: pcsamp experiment calling openss.
[openss]: Setting up offline raw data directory in /p/lscratchrzb/jeg/offline-oss
[openss]: Running offline pcsamp experiment using the command:
"srun -ppdebug -n 256 /collab/usr/global/tools/openspeedshop/oss-
dev/x8664/oss_offline_v2.1u6/bin/ossrun -c pcsamp ./smg2000 -n 60 60 60"

Running with these driver parameters:
 (nx, ny, nz)    = (60, 60, 60)
 (Px, Py, Pz)    = (256, 1, 1)
 (bx, by, bz)    = (1, 1, 1)
 (cx, cy, cz)    = (1.000000, 1.000000, 1.000000)
 (n_pre, n_post) = (1, 1)
 dim             = 3
 solver ID       = 0
=============================================
Struct Interface:
=============================================
Struct Interface:
 wall clock time = 0.020830 seconds
 cpu clock time  = 0.030000 seconds
=============================================
Setup phase times:
=============================================
SMG Setup:
 wall clock time = 0.451188 seconds
```

```
 cpu clock time  = 0.460000 seconds
===========================================
Solve phase times:
===========================================
SMG Solve:
 wall clock time = 2.707334 seconds
 cpu clock time  = 2.720000 seconds
Iterations = 7
Final Relative Residual Norm = 1.446921e-07
[openss]: Converting raw data from /p/lscratchrzb/jeg/offline-oss into temp file X.0.openss
Processing raw data for smg2000 ...
Processing processes and threads ...
Processing performance data ...
Processing symbols ...
Resolving symbols for /g/g24/jeg/demos/workshop_demos/mpi/smg2000/test/smg2000
Resolving symbols for /lib64/ld-2.12.so
Resolving symbols for /collab/usr/global/tools/openspeedshop/oss-
dev/x8664/oss_offline_v2.1u6/lib64/openspeedshop/pcsamp-rt-offline.so
Resolving symbols for /collab/usr/global/tools/openspeedshop/oss-
dev/x8664/krellroot_v2.1u6/lib64/libmonitor.so.0.0.0
Resolving symbols for /usr/local/tools/mvapich-gnu-1.2/lib/shared/libmpich.so.1.0
Resolving symbols for /lib64/libc-2.12.so
Resolving symbols for /lib64/libpthread-2.12.so
Resolving symbols for /usr/lib64/libpsm_infinipath.so.1.14
Resolving symbols for /usr/lib64/libinfinipath.so.4.0
Updating database with symbols ...
Finished ...

[openss]: Restoring and displaying default view for:
/g/g24/jeg/demos/workshop_demos/mpi/smg2000/test/smg2000-pcsamp.openss
[openss]: The restored experiment identifier is:  -x 1

Exclusive   % of CPU  Function (defining location)
 CPU time      Time
      in
 seconds.
272.1200  34.202  hypre_SMGResidual (smg2000: smg_residual.c,152)
195.0000  24.509  hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
 80.0100  10.056  psm_mq_ipeek (libpsm_infinipath.so.1.14)
 70.7600   8.893  ips_ptl_poll (libpsm_infinipath.so.1.14)
 16.1300   2.027  hypre_SemiInterp (smg2000: semi_interp.c,126)
 15.5600   1.955  __psmi_poll_internal (libpsm_infinipath.so.1.14)
 14.2300   1.788  hypre_SemiRestrict (smg2000: semi_restrict.c,125)
  6.5700   0.825  hypre_SMGAxpy (smg2000: smg_axpy.c,27)
  6.0600   0.761  MPIR_Pack_Hvector (libmpich.so.1.0: dmpipk.c,31)
  5.9500   0.747  ipath_dwordcpy (libinfinipath.so.4.0)
  5.7900   0.727  MPID_DeviceCheck (libmpich.so.1.0: psmcheck.c,35)
 …
 …
```

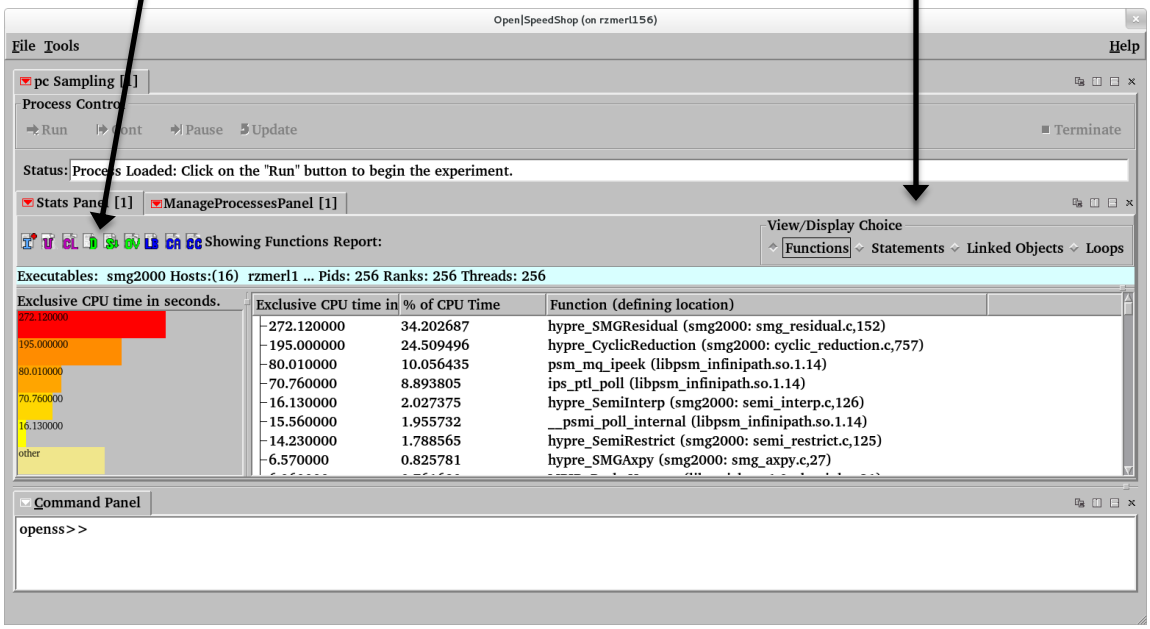
When the application completes a default report will be printed on screen. The performance information gathered during execution of the experiment will be stored in a database called smg2000-pcsamp.openss. You can use the O|SS GUI to analyze the data in detail. Run the openss command to load that database file or open the file directly using the "-f" option:

```
> openss –f smg2000-pcsamp.openss
```

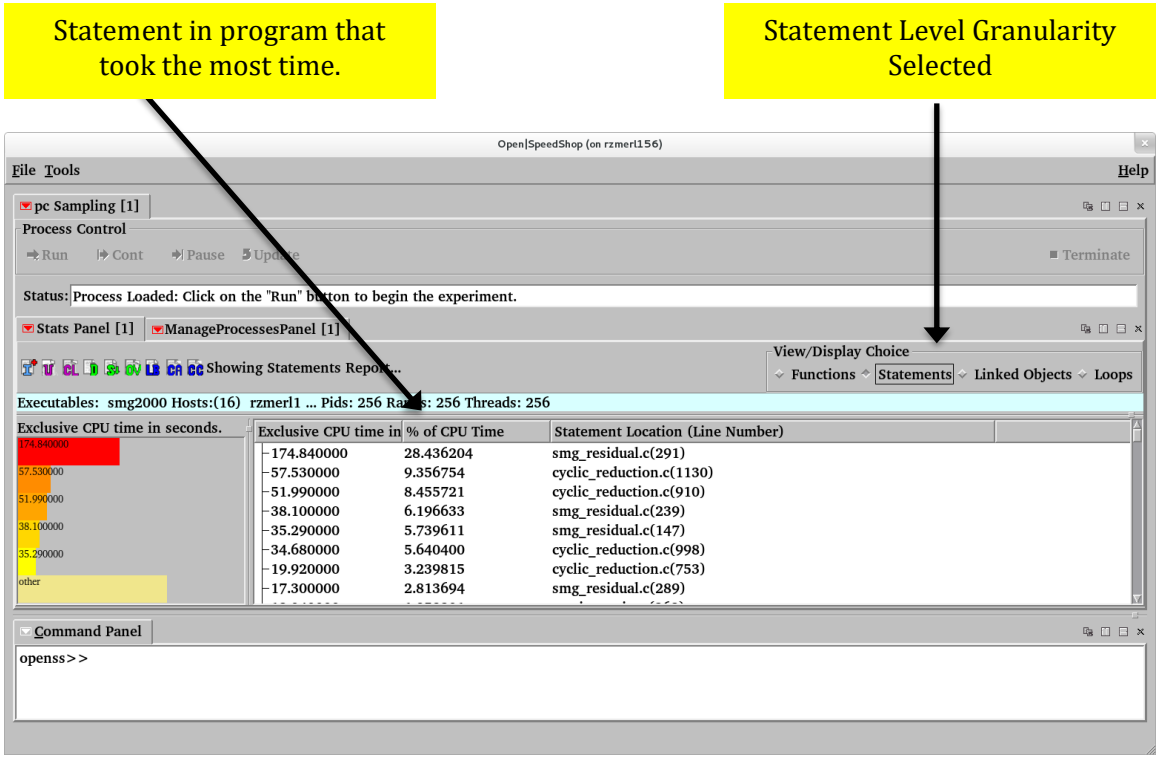
Below we show basic examples of how to use the GUI to view the output database file created by the convenience script.

View Type Choices (D for Default selected and shown) LB: Load Balance, CA: Cluster Analysis, and others available.

View Granularity Choices (Function level selected) Statement, Library, and Loop level are available.



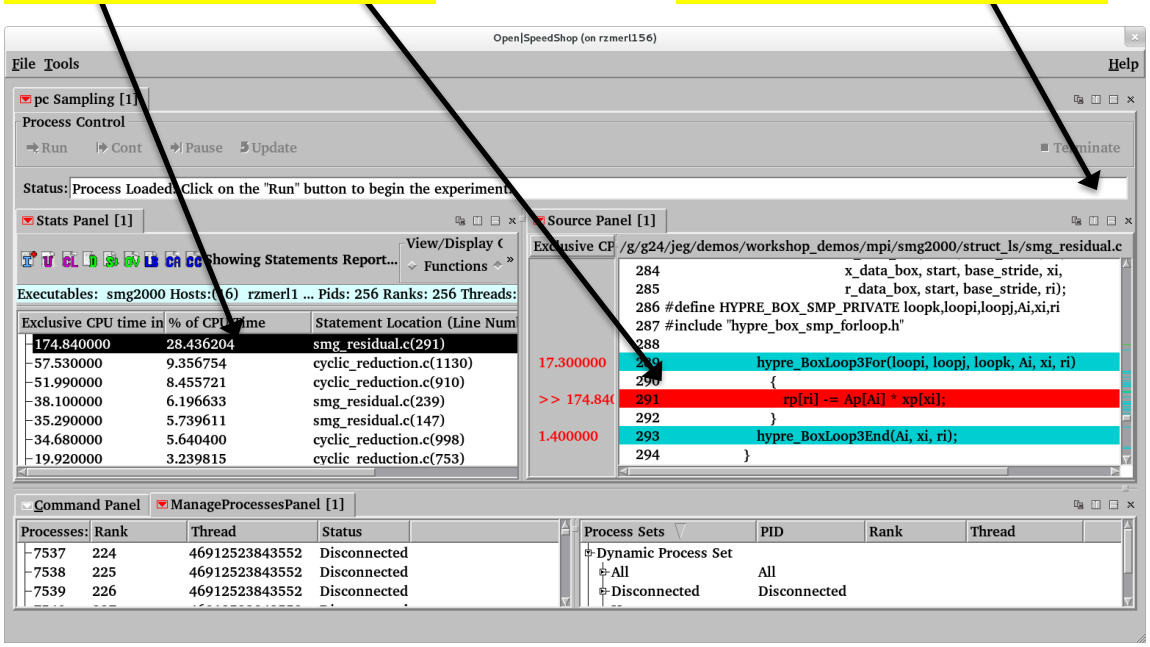
You can choose to view data for the Function, Statement, Linked Object, or Loop level granularity. To switch from one view type to another, **first select the view granularity** (Function, Statement, Linked Object, or Loop), and **then select the type of view**. For the default views, select the "D" icon.



You can manipulate the windows within the GUI and double click functions or statements to see the source code directly.

Double Click to open Source View and focus on source line (291)

Use window controls to split/arrange windows. Vertical split was used here.



1.4 How to Gather and Understand Profiles

A profile is the aggregated measurements collected during the experiment. Profiles look at code sections over time. There are advantages to using profiles since they reduce the size of performance data and typically the data is collected with low overhead. So profiles can provide a good overview of the performance of an application.

The disadvantage of using a profile is that you are required to know beforehand how to aggregate the data collected. Also, since profiles provide more of an overview, they omit the performance details of individual events. There could also be an issue where selecting an inappropriate sampling frequency could skew the results of the profile.

Statistical Performance Analysis is a standard profiling technique; it involves interrupting the execution of the application in periodic intervals to record the location of the execution (Program Counter value). It can also be used to collect additional data like stack traces or hardware counters. Again the advantage of this method is its low overhead. It is good for getting an overview of the program and finding the hotspots (time intensive areas) within the program.

The sampling experiments available in O|SS include Program Counter Sampling, Call Path Profiling and Hardware Counter. The Program Counter Sampling experiment (osspcsamp) provides approximate CPU time for each line and function in the program. The Call Path Profiling experiment (ossusertime) provides inclusive vs. exclusive CPU time (see section 4.2), and also includes call stacks. There is a number of Hardware Counter experiments (osshwc, osshwctime) that sample hardware counter overflows and osshwcsamp that can periodically sample up to six hardware counter events.

2.1 Program Counter Sampling (pcsamp) Experiment

A flat profile will answer the basic question: “Where does my code spend its time?” This will be displayed as a list of code elements with varying granularity, i.e. statements, functions and libraries (linked objects), with the time spent at each function. Flat profiling can be done through sampling, which allows us to avoid the overhead of direct measurements. We must ensure we request a sufficient number of samples (sampling rate) to get an accurate result.

O|SS can use this information to identify the critical regions. The profile shows computationally intensive code regions by displaying the time spent per function or per statement. While viewing this we must ask ourselves:

- "Are those the functions/statements that were expected relative to taking the most time?"
- "Does this match the computational kernels?"
- "Are any runtime functions taking a lot of time?"

We want to identify any components that are bottlenecks. We can do this by viewing the profile aggregated by shared (linked) objects, making sure the correct or expected modules are present, then analyze the impact of those support and/or runtime libraries.

2.1.1 Program Counter Sampling (pcsamp) experiment performance data gathering

The program counter sampling experiment convenience script is "osspcsamp". Use this convenience script in this manner to gather address values for where O|SS periodically interrupted the application being run and took an address sample:

```
osspcsamp "how you normally run your application" < sampling rate>
```

An example of flat profiling would be running the program counter sampling in O|SS. We will run the convenience script on our test program smg2000:

```
> osspcsamp "mpirun –np 256 smg2000 –n 50 50 50"
```

It is recommended that you compile your code with the –g option in order to see the statements in the sampling. The pcsamp experiment also takes a sampling frequency as an optional parameter, the available parameters are high (200 samples per second), low (50 samples per second) and the default value is 100 samples per second. If we wanted to run the same experiment with the high sampling rate, we would simply issue the command:

```
> osspcsamp "mpirun –np 256 smg2000 –n 50 50 50" high
```

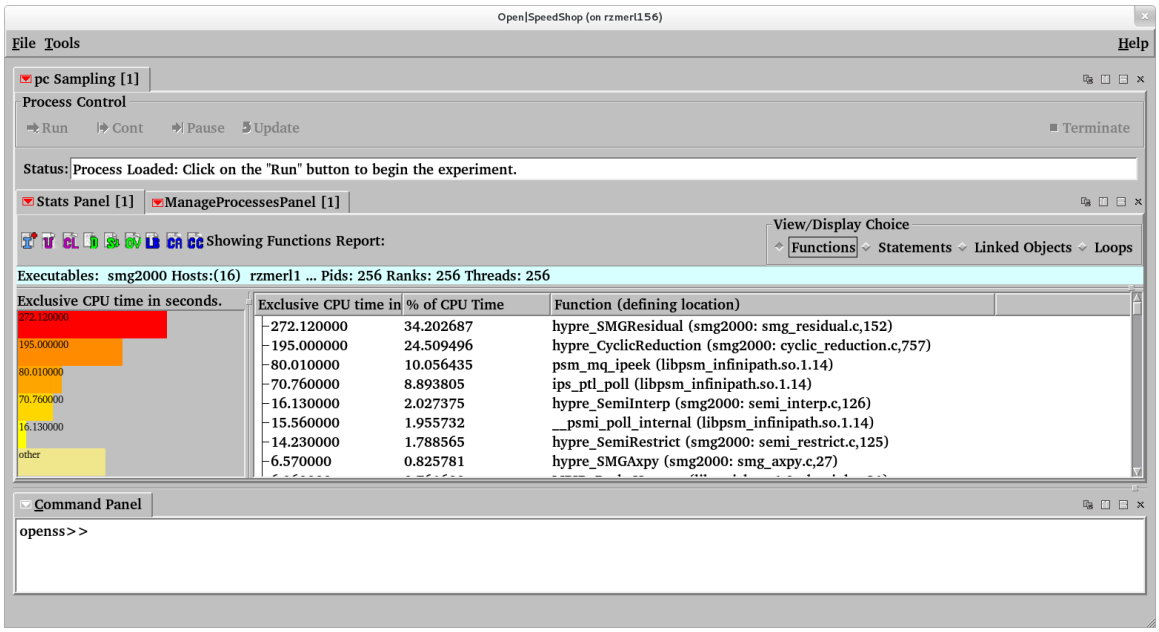
2.1.1.1 Program Counter Sampling (pcsamp) experiment parameters

The pcsamp experiment is timer based. What that means is a timer is used to periodically interrupt the processor. For the pcsamp experiment, each time the timer interrupts the processor; the address in the program counter is read up and saved. This allows O|SS to map those address values back to the source when the pcsamp performance information is viewed via the command line interface (CLI) or the graphical user interface (GUI) tool.

In the next example the user is choosing to only sample 45 times a second instead of the default 100 times a second. Why would you want to do this? One reason would be to save database size; a lower sampling rate may still give an accurate portrayal of the application behavior.

2.1.2 Program Counter Sampling (pcsamp) experiment performance data viewing with GUI

We can view the results of this flat profile in the O|SS GUI by using the “openss –f <database filename>” command.



2.1.3 Program Counter Sampling (pcsamp) experiment performance data viewing with CLI

After running a program counter experiment via the command:

osspcsamp “mpirun –np 4 ./smg2000 –n 65 65 65”

one can view the data in the command line interface (CLI) by opening the newly created database file by using the command:

openss –cli –f smg2000-pcsamp-0.openss

Once inside the CLI, there are several commands that can be used to view this performance information. Here are some examples of CLI commands one could use.

The default view is shown by using the expview command with no arguments.

```
openss>>expview

Exclusive   % of CPU  Function (defining location)
 CPU time      Time
    in
```

```
 seconds.
 7.640000  41.657579  hypre_SMGResidual (smg2000: smg_residual.c,152)
 4.840000  26.390403  hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
 0.800000   4.362050  mca_btl_vader_check_fboxes (libmpi.so.12.0.2: btl_vader_fbox.h,184)
 0.450000   2.453653  unpack_predefined_data (libopen-pal.so.13.0.2: opal_datatype_unpack.h,34)
 0.400000   2.181025  hypre_SemiInterp (smg2000: semi_interp.c,126)
 0.370000   2.017448  __memcpy_ssse3_back (libc-2.17.so)
 0.350000   1.908397  pack_predefined_data (libopen-pal.so.13.0.2: opal_datatype_pack.h,35)
 0.330000   1.799346  hypre_SemiRestrict (smg2000: semi_restrict.c,125)
 0.310000   1.690294  opal_progress (libopen-pal.so.13.0.2: opal_progress.c,151)
 0.180000   0.981461  opal_sys_timer_get_cycles (libopen-pal.so.13.0.2: timer.h,43)
...
...
```

To view the performance information by statement granularity use the –v statements argument to expview. The top of the list shows the statement in the application that took the most time for this particular run of smg2000. Results may vary when running on other platforms and/or with different arguments to smg2000 or different compiler options.

```
openss>>expview -v statements

Exclusive   % of CPU  Statement Location (Line Number)
 CPU time      Time
     in
 seconds.
 5.790000  35.304878  smg_residual.c(289)
 1.410000   8.597561  cyclic_reduction.c(1130)
 1.080000   6.585366  smg_residual.c(238)
 0.830000   5.060976  cyclic_reduction.c(910)
 0.690000   4.207317  cyclic_reduction.c(999)
 0.420000   2.560976  cyclic_reduction.c(1061)
 0.410000   2.500000  smg_residual.c(287)
 0.330000   2.012195  cyclic_reduction.c(853)
 0.260000   1.585366  opal_datatype_unpack.h(59)
 0.260000   1.585366  cyclic_reduction.c(1000)
 0.240000   1.463415  btl_vader_fbox.h(197)
 0.230000   1.402439  semi_restrict.c(262)
 0.200000   1.219512  opal_datatype_pack.h(60)
 0.180000   1.097561  cyclic_reduction.c(1131)
 0.150000   0.914634  semi_interp.c(294)
...
...
```

One can also see the performance data for smg2000 at the library (linked object) granularity by using the –v linkedobjects argument to expview. What this tells is how much time was spent in each of the libraries that Open|SpeedShop took samples of the program counter in. This gives an overview of where the time was spent from the library perspective. If the MPI library time was very high, it may indicate that this run was not effectively using MPI. You may have load imbalance.

```
openss>>expview -v linkedobjects
```

```
Exclusive   % of CPU  LinkedObject
 CPU time      Time
     in
 seconds.
14.180000  76.981542  smg2000
 1.860000  10.097720  libmpi.so.12.0.2
 1.630000   8.849077  libopen-pal.so.13.0.2
 0.740000   4.017372  libc-2.17.so
 0.010000   0.054289  ld-2.17.so
openss>>
```

Another level of granularity to view the performance information at it at the loop level. Using –v loops as an argument will display the time spent in the loops. For example, the first line in the display shows that a loop starting at line 204 in smg_residual.c was the loop that took the most time. Open|SpeedShop cannot accurately determine the loops end statement. So, only the starting line number is given in the display.

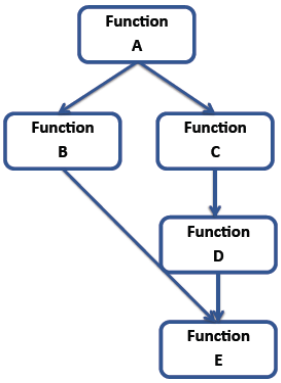
```
openss>>expview -v loops

Exclusive   % of CPU  Loop Start Location (Line Number)
 CPU time      Time
     in
 seconds.
 7.640000  32.345470  smg_residual.c(204)
 2.240000   9.483489  cyclic_reduction.c(1022)
 2.140000   9.060119  cyclic_reduction.c(882)
 0.790000   3.344623  btl_vader_fbox.h(188)
 0.550000   2.328535  cyclic_reduction.c(1034)
 0.430000   1.820491  cyclic_reduction.c(851)
 0.430000   1.820491  cyclic_reduction.c(851)
 0.430000   1.820491  cyclic_reduction.c(851)
 0.430000   1.820491  cyclic_reduction.c(835)
 0.410000   1.735817  opal_datatype_unpack.h(58)
…
…
```

Another useful CLI command is expstatus. This gives a summary of the metadata for the Open|SpeedShop experiment. This

```
openss>>expstatus

  Experiment definition
{ # ExpId is 1, Status is Terminated, Saved database is smg2000-pcsamp-0.openss
    Performance data spans 4.773728 seconds  from 2016/11/22 07:43:30 to 2016/11/22 07:43:35
  Executables Involved:
            smg2000
  Currently Specified Components:
    -h localhost -p 8090 -t 0 -r 1 (smg2000)
    -h localhost -p 8091 -t 0 -r 2 (smg2000)
    -h localhost -p 8092 -t 0 -r 3 (smg2000)
    -h localhost -p 8089 -t 0 -r 0 (smg2000)
  Previously Used Data Collectors:
```

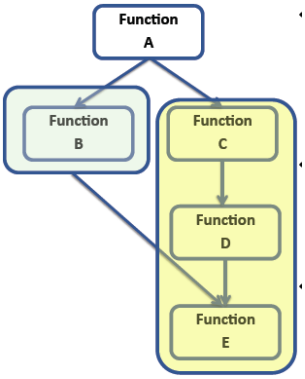
```
            pcsamp
          Metrics:
    pcsamp::percent
 pcsamp::threadAverage
   pcsamp::threadMax
   pcsamp::threadMin
      pcsamp::time
   Parameter Values:
pcsamp::sampling_rate =  100
    Available Views:
            pcsamp
```

3.1 Call Path Profiling (usertime) Experiment



The call path profiling (usertime) experiment can add some information that is missing from the flat profiles. It is able to distinguish routines called from multiple callers, and understand the call invocation history. This provides context for the performance data. It also gathers stack traces for each performance sample and only aggregates samples with equal stack traces. For the user, this simplifies the view by showing the caller/callee relationship. It can also highlight the hot call paths, the paths through the application that take the most time.

The call path profiling experiment also provides inclusive and exclusive time. Exclusive time is the time spent inside a function only, for example function B. Whereas inclusive time is the time spend inside a function and its children, for example the full chain of function C, D and E.



The call path profiling experiment is similar to the program counter sampling experiment since it collects program counter information, except that it collects call stack information at every sample. There are, of course, tradeoffs with that, you obtain additional context information from the call stacks but there is now a higher overhead and necessarily lower sampling rate.

3.1.1 Call Path Profiling (usertime) experiment performance data gathering

We can run the call path profiling experiment using the O|SS convenience script on our test program smg2000:

```
> ossusertime "mpirun –np 256 smg2000 –n 50 50 50"
```

Again it is recommended that you compile your code with the –g option in order to see the statements in the sampling. The usertime experiment also takes a sampling frequency as an optional parameter, the available parameters are high (70 samples per second), low (18 samples per second) and the default value is 35 samples per second. Note that these sample rates are lower than the pcsamp experiment because of the increased amount of data being collected. If we wanted to run the same experiment with the low sampling rate, we would simply issue the command:

```
> ossusertime “mpirun –np 256 smg2000 –n 50 50 50” low
```

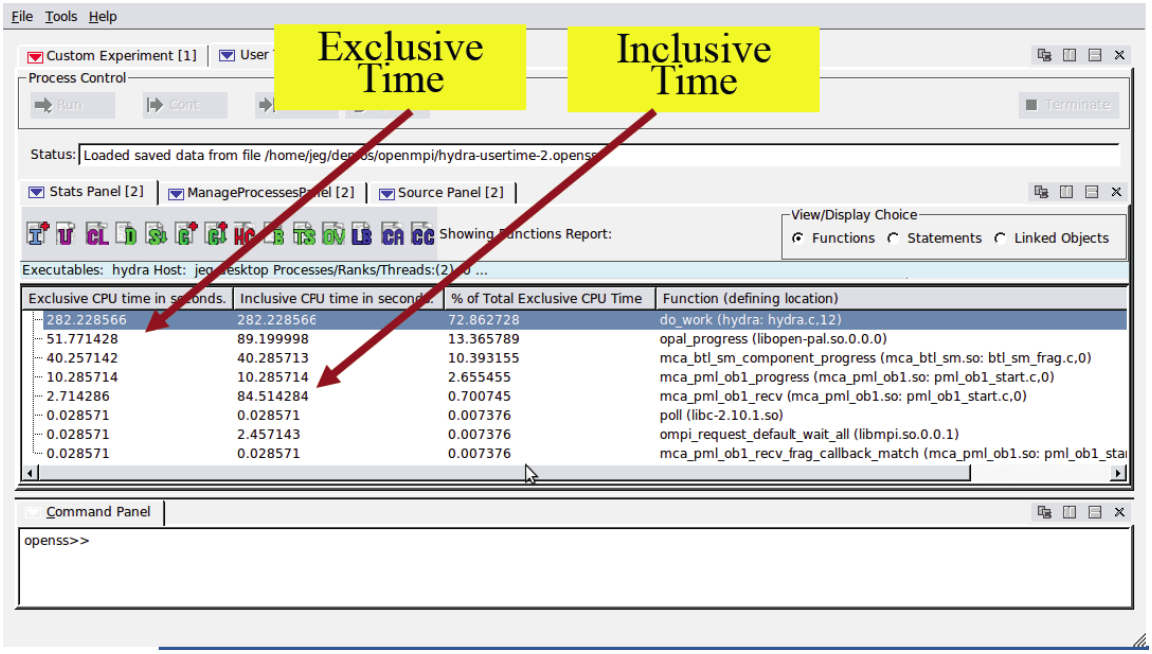
Here is an example run of an usertime experiment with full output:

```
ossusertime "mpirun -np 4 ./smg2000 -n 65 65 65"
[openss]: usertime experiment using the default sampling rate: "35".
Creating topology file for frontend host localhost
Generated topology file: ./cbtfAutoTopology
Running usertime collector.
Program: mpirun -np 4 ./smg2000 -n 65 65 65
Number of mrnet backends: 4
Topology file used: ./cbtfAutoTopology
executing mpi program: mpirun -np 4  cbtfrun  --mpi  --mrnet  -c usertime ./smg2000 -n 65 65 65
Running with these driver parameters:
  (nx, ny, nz)    = (65, 65, 65)
  (Px, Py, Pz)    = (4, 1, 1)
  (bx, by, bz)    = (1, 1, 1)
  (cx, cy, cz)    = (1.000000, 1.000000, 1.000000)
  (n_pre, n_post) = (1, 1)
  dim             = 3
  solver ID       = 0
=============================================
Struct Interface:
=============================================
Struct Interface:
  wall clock time = 0.023957 seconds
  cpu clock time  = 0.030000 seconds
=============================================
Setup phase times:
=============================================
SMG Setup:
  wall clock time = 0.594738 seconds
  cpu clock time  = 0.590000 seconds
=============================================
Solve phase times:
=============================================
SMG Solve:
  wall clock time = 4.306247 seconds
  cpu clock time  = 4.280000 seconds

Iterations = 7
Final Relative Residual Norm = 1.760588e-07

All Threads are finished.
default view for ./smg2000-usertime-14.openss
[openss]: The restored experiment identifier is:  -x 1
Performance data spans 5.271756 seconds  from 2016/11/11 08:06:12 to 2016/11/11 08:06:17

Exclusive  Inclusive      % of  Function (defining location)
 CPU time   CPU time     Total
      in        in  Exclusive
 seconds.   seconds.   CPU Time
 9.000000   9.800000  45.718433  hypre_SMGResidual (smg2000: smg_residual.c,152)
 4.171428   7.057143  21.190131  hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
 0.542857   0.571429   2.757620  hypre_SemiInterp (smg2000: semi_interp.c,126)
```

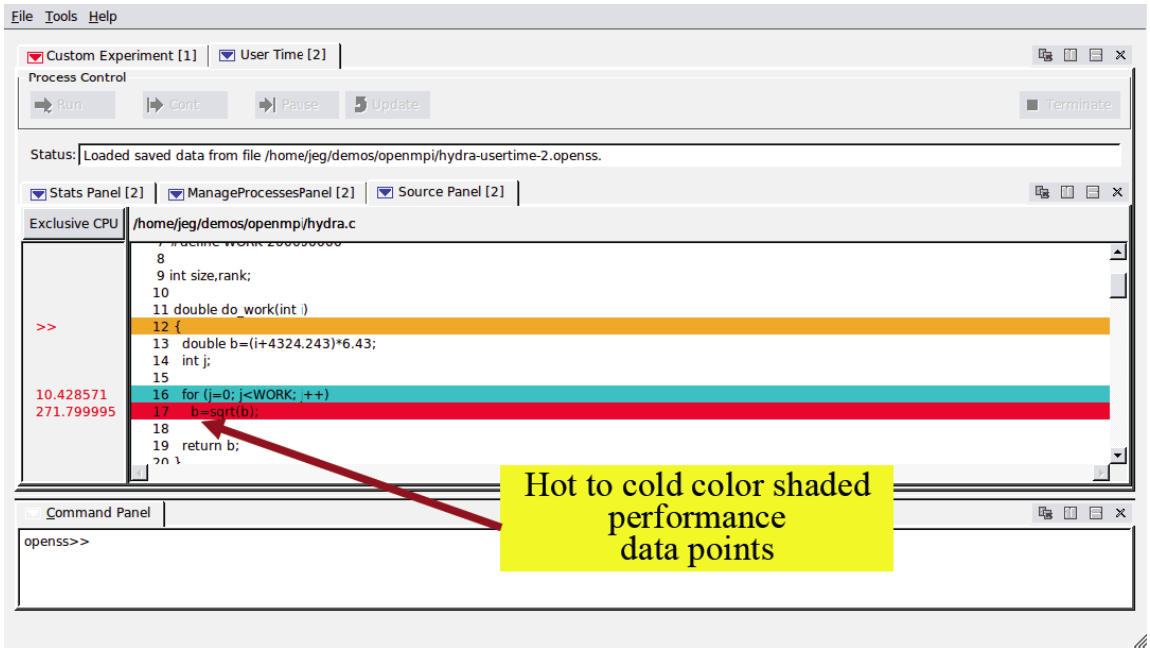
```
0.514286  1.542857  2.612482  mca_btl_vader_check_fboxes (libmpi.so.12.0.2: btl_vader_fbox.h,184)
0.514286  0.942857  2.612482  pack_predefined_data (libopen-pal.so.13.0.2: opal_datatype_pack.h,35)
0.485714  0.485714  2.467344  __memcpy_ssse3_back (libc-2.17.so)
0.457143  0.514286  2.322206  unpack_predefined_data (libopen-pal.so.13.0.2: opal_datatype_unpack.h,34)
0.314286  2.314286  1.596517  opal_progress (libopen-pal.so.13.0.2: opal_progress.c,151)
0.285714  0.314286  1.451379  hypre_SemiRestrict (smg2000: semi_restrict.c,125)
0.257143  0.257143  1.306241  hypre_StructAxpy (smg2000: struct_axpy.c,25)
0.228571  0.228571  1.161103  hypre_SMGAxpy (smg2000: smg_axpy.c,27)
0.171429  0.171429  0.870827 hypre_SMGSetStructVectorConstantValues (smg2000: smg.c,379)
```

3.1.2 Call Path Profiling (usertime) experiment performance data viewing with GUI

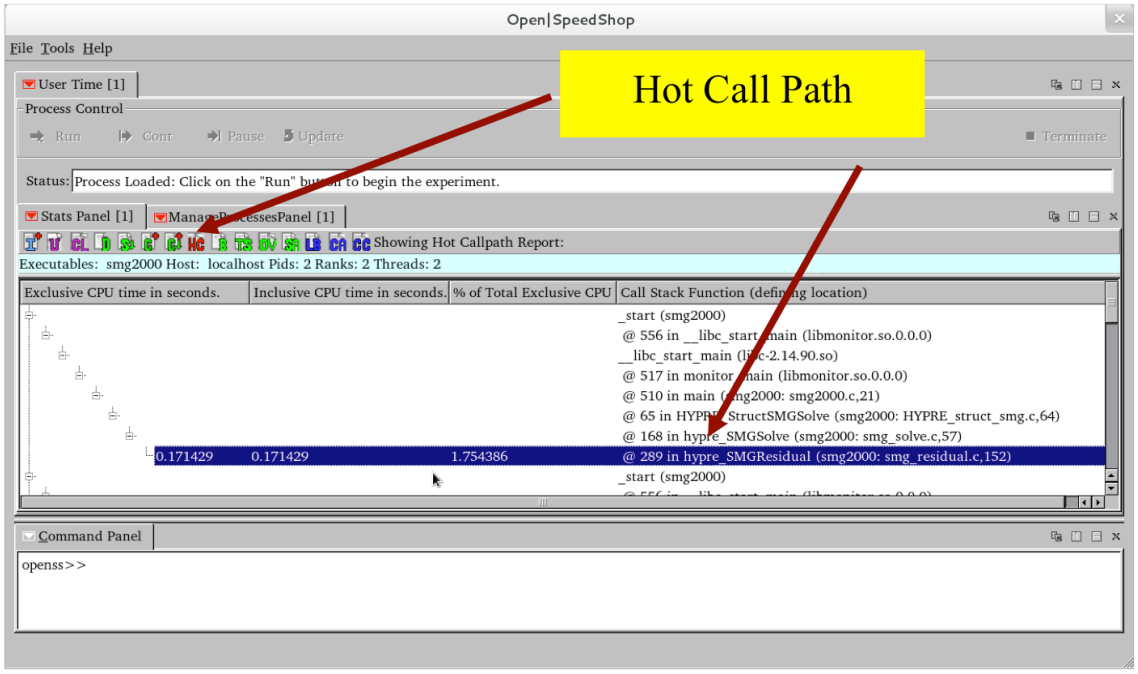
We can view the results of this experiment in the O|SS GUI. The view is similar to the pcsamp view but this time the inclusive CPU time is also shown.



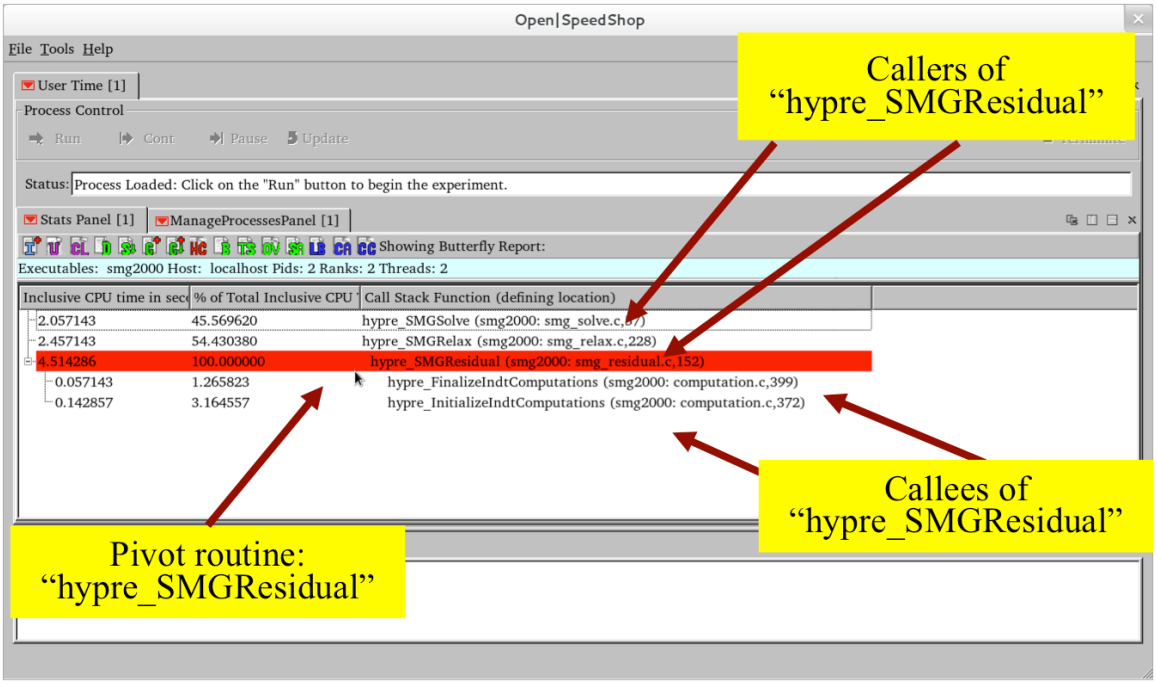
Below we see the Exclusive CPU time on highlighted lines that indicate relatively high CPU times.



While performance tools will point out potential bottlenecks and hot areas it is still up to the user to interpret most data in the correct context as well as note areas of the code you may want to probe further. If the inclusive and exclusive times are similar this means the child executions are insignificant (with respect to CPU time) and it may not be useful to profile below this layer. If the inclusive time is significantly greater than the exclusive time, then you should focus your attention to the execution times of the children.



The stack trace views in O|SS are similar to the well-known Unix profiling tool gprof.



3.1.3 Call Path Profiling (usertime) experiment performance data viewing with CLI

The table below describes information that is included in the usertime experiment default view.

Column Name	Column Definition
Exclusive CPU Time	Aggregated total exclusive time spent in the application function corresponding to this row of data.
% of CPU Time	Percentage of exclusive time spent in the function corresponding to this row of data relative to the total application exclusive time for all the application functions.
Inclusive CPU Time	Aggregated total inclusive time spent in the application function corresponding to this row of data.

To load a database file into the CLI, use this form of the openss client:

```
$ openss -cli -f ./smg2000-usertime-14.openss
```

This is a default CLI view for the usertime experiment, restricted to the top 10 time taking functions. Using the experiment name and the number of items that are desired to be displayed limits the output to those items.

```
openss>>expview usertime10

Exclusive  Inclusive      % of  Function (defining location)
 CPU time   CPU time      Total
     in        in  Exclusive
 seconds.   seconds.   CPU Time
 9.000000   9.800000  45.718433  hypre_SMGResidual (smg2000: smg_residual.c,152)
 4.171428   7.057143  21.190131  hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
 0.542857   0.571429   2.757620  hypre_SemiInterp (smg2000: semi_interp.c,126)
 0.514286   1.542857   2.612482  mca_btl_vader_check_fboxes (libmpi.so.12.0.2:
btl_vader_fbox.h,184)
 0.514286   0.942857   2.612482  pack_predefined_data (libopen-pal.so.13.0.2:
opal_datatype_pack.h,35)
 0.485714   0.485714   2.467344  __memcpy_ssse3_back (libc-2.17.so)
 0.457143   0.514286   2.322206  unpack_predefined_data (libopen-pal.so.13.0.2:
opal_datatype_unpack.h,34)
 0.314286   2.314286   1.596517  opal_progress (libopen-pal.so.13.0.2: opal_progress.c,151)
 0.285714   0.314286   1.451379  hypre_SemiRestrict (smg2000: semi_restrict.c,125)
 0.257143   0.257143   1.306241  hypre_StructAxpy (smg2000: struct_axpy.c,25)
```

The display below shows the top 10 time taking statements in the program:

```
openss>>expview -v statements usertime10

Exclusive  Inclusive      % of  Statement Location (Line Number)
 CPU time   CPU time      Total
     in        in  Exclusive
 seconds.   seconds.   CPU Time
 7.085714   7.085714  41.471572  smg_residual.c(289)
 1.371429   1.371429   8.026756  cyclic_reduction.c(1130)
 1.314286   1.314286   7.692308  smg_residual.c(238)
 0.828571   0.828571   4.849498  cyclic_reduction.c(910)
 0.485714   0.485714   2.842809  cyclic_reduction.c(999)
 0.285714   0.285714   1.672241  smg_residual.c(287)
 0.285714   0.285714   1.672241  cyclic_reduction.c(853)
 0.285714   0.285714   1.672241  cyclic_reduction.c(1000)
 0.257143   0.257143   1.505017  semi_interp.c(294)
 0.228571   0.228571   1.337793  opal_datatype_unpack.h(59)
```

The top 10 time consuming loops in the application are shown below. The line numbers (for example: 204 in first entry) is the line that the loop begins. Our static analysis does not provide us with the ending line number for the loop, but it is the line that corresponds to the end of the logical loop construct.

```
openss>>expview -v loops usertime10

Exclusive  Inclusive      % of  Loop Start Location (Line Number)
 CPU time   CPU time      Total
     in        in  Exclusive
 seconds.   seconds.   CPU Time
 8.971428   9.771428  37.649880  smg_residual.c(204)
 1.914286   3.257143   8.033573  cyclic_reduction.c(1022)
```

```
 1.885714   3.400000   7.913669  cyclic_reduction.c(882)
 0.857143   0.885714   3.597122  cyclic_reduction.c(889)
 0.485714   1.514286   2.038369  btl_vader_fbox.h(188)
 0.400000   0.828571   1.678657  opal_datatype_pack.h(59)
 0.371429   0.428571   1.558753  opal_datatype_unpack.h(58)
 0.371429   0.400000   1.558753  semi_interp.c(238)
 0.371429   0.400000   1.558753  cyclic_reduction.c(835)
 0.371429   0.400000   1.558753  semi_interp.c(258)
openss>>
```

The time spent in the libraries of the application are shown here:

```
openss>>expview -v linkedobjects

Exclusive  Inclusive      % of  LinkedObject
 CPU time   CPU time     Total
     in        in  Exclusive
 seconds.   seconds.   CPU Time
15.514285  19.742857  78.581766  smg2000
 1.800000   3.400000   9.117221  libopen-pal.so.13.0.2
 1.400000   3.885714   7.091172  libmpi.so.12.0.2
 1.028571  19.742857   5.209841  libc-2.17.so
```

The top three time consuming call paths in the application are shown here:

```
openss>>expview -v fullstack usertime3

Exclusive  Inclusive      % of  Call Stack Function (defining location)
 CPU time   CPU time     Total
     in        in  Exclusive
 seconds.   seconds.   CPU Time
                      _start (smg2000)
                      > @ 556 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
                      >>__libc_start_main (libc-2.17.so)
                      >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
                      >>>> @ 510 in main (smg2000: smg2000.c,21)
                      >>>>> @ 65 in HYPRE_StructSMGSolve (smg2000: HYPRE_struct_smg.c,64)
                      >>>>>> @ 224 in hypre_SMGSolve (smg2000: smg_solve.c,57)
 0.800000   0.800000   4.052098  >>>>>>> @ 289 in hypre_SMGResidual (smg2000:
smg_residual.c,152)
                      _start (smg2000)
                      > @ 556 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
                      >>__libc_start_main (libc-2.17.so)
                      >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
                      >>>> @ 510 in main (smg2000: smg2000.c,21)
                      >>>>> @ 65 in HYPRE_StructSMGSolve (smg2000: HYPRE_struct_smg.c,64)
                      >>>>>> @ 168 in hypre_SMGSolve (smg2000: smg_solve.c,57)
 0.400000   0.400000   2.026049  >>>>>>> @ 289 in hypre_SMGResidual (smg2000:
smg_residual.c,152)
                      _start (smg2000)
                      > @ 556 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
                      >>__libc_start_main (libc-2.17.so)
```

```
                    >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
                    >>>> @ 510 in main (smg2000: smg2000.c,21)
                    >>>>> @ 65 in HYPRE_StructSMGSolve (smg2000: HYPRE_struct_smg.c,64)
                    >>>>>> @ 164 in hypre_SMGSolve (smg2000: smg_solve.c,57)
                    >>>>>>> @ 325 in hypre_SMGRelax (smg2000: smg_relax.c,228)
                    >>>>>>>> @ 224 in hypre_SMGSolve (smg2000: smg_solve.c,57)
 0.400000   0.400000   2.026049 >>>>>>>>> @ 289 in hypre_SMGResidual (smg2000:
smg_residual.c,152)
```

Here the Butterfly view shows the functions calling hypre_SMGSolve and also the functions hypre_SMGSolve calls. Hypre_SMGSolve is the pivot point in this view.

```
openss>>expview -vbutterfly -f hypre_SMGSolve

Inclusive  % of Total  Call Stack Function (defining location)
 CPU time   Inclusive
     in    CPU Time
 seconds.
17.200000   94.654088  <HYPRE_StructSMGSolve (smg2000: HYPRE_struct_smg.c,64)
 0.971429    5.345912    <hypre_SMGRelax (smg2000: smg_relax.c,228)
18.171428  100.000000      hypre_SMGSolve (smg2000: smg_solve.c,57)
16.285714   89.622642  >hypre_SMGRelax (smg2000: smg_relax.c,228)
 1.428571    7.861635    >hypre_SMGResidual (smg2000: smg_residual.c,152)
 0.171429    0.943396    >hypre_SemiInterp (smg2000: semi_interp.c,126)
 0.114286    0.628931    >hypre_SemiRestrict (smg2000: semi_restrict.c,125)
 0.114286    0.628931    >hypre_StructAxpy (smg2000: struct_axpy.c,25)
 0.057143    0.314465   >hypre_StructInnerProd (smg2000: struct_innerprod.c,32)
```

Here the performance information for only percent is displayed because the metric percent was given to the expview command.

```
openss>>expview -m percent usertime9

    % of  Function (defining location)
   Total
Exclusive
    Time
45.718433  hypre_SMGResidual (smg2000: smg_residual.c,152)
21.190131  hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
 2.757620  hypre_SemiInterp (smg2000: semi_interp.c,126)
 2.612482  mca_btl_vader_check_fboxes (libmpi.so.12.0.2: btl_vader_fbox.h,184)
 2.612482  pack_predefined_data (libopen-pal.so.13.0.2: opal_datatype_pack.h,35)
 2.467344  __memcpy_ssse3_back (libc-2.17.so)
 2.322206  unpack_predefined_data (libopen-pal.so.13.0.2: opal_datatype_unpack.h,34)
 1.596517  opal_progress (libopen-pal.so.13.0.2: opal_progress.c,151)
 1.451379  hypre_SemiRestrict (smg2000: semi_restrict.c,125)
```

4 How to Relate Data to Architectural Properties

Performance Application Programming Interface (PAPI) allows access to hardware counters through APIs and simple runtime tools. You can find more information on PAPI at http://icl.cs.utk.edu/papi.

O|SS provides three hardware counter experiments that are implemented on top of PAPI. It provides access to PAPI and native counters like data cache misses, TLB misses and bus accesses.

There are a few basic models to follow in hardware counter experiments. The first is thresholding, where the user selects a counter and the application runs until a fixed number of events have been reached on that counter. Then a PC sample is taken at that location every time the counter increases by the preset fixed number. The ideal threshold, the fixed number at which to monitor, is dependent on the application. Another model is a timer based sampling where the counters are checked at given time intervals.

O|SS provides three hardware counter experiments, hwc for flat hardware counter profiles using a single hardware counter, hwctime for profiles with stack traces using a single hardware counter and hwcsamp for PC sampling with multiple hardware counters. Both osshwc and osshwctime support non-derived PAPI presets, all non-derived events are reported by "papi_avail –a". You can also see the available events by running the experiments (osshwc or osshwctime) with no arguments. The experiments include all native events for that specific architecture. Some PAPI event names are listed in sections below, but please see the PAPI documentation for the full list.

The threshold you choose depends on the application, you want to balance overhead with accuracy. Remember a higher threshold will record less samples. Rare events need a smaller threshold or that information may be lost (never triggered and recorded). Frequent events should use a larger threshold, to reduce the overhead of collecting the information. Selecting the right threshold can take experience or some trial and error.

HINT: Running the sampling based hardware counter experiment, osshwcsamp, can help you get an idea for a threshold value to try when running the osshwc and osshwctime experiments which are threshold based. Since the ideal number of events (threshold) depends on the application and the selected counter, for events other than the default, the hwcsamp experiment can be used to get an overview of counter activity.

The default threshold is set to a very large value to match the default event (PAPI_TOT_CYC). For all other events, it is recommended that the user run hwcsamp first to get an idea of how many times a particular event occurs (the count

of the event) during the life of the program. A reasonable threshold can be determined from the hwcsamp data by determining the average counts per thread of execution and then setting the hwc/hwctime threshold to some small fraction of that. For example, if you see 1333333333 PAPI_L1_DCM's over the life of the program when running the hwcsamp experiment and there were 524 processes used during the application run, the this is the formula you could use to find a reasonable threshold for the hwc and hwctime experiments when using the PAPI_L1_DCM event for the same application. So the formula that could be used is as follows:

(Average counts per thread) / 1000 == Threshold for hwc/hwctime
In this case:
(1333333333/524)/1000 == 2544529/1000 == 2545

Using this formula one could use 2545 as the threshold value in hwc and hwctime for PAPI_L1_DCM and expect to get a reasonable data sample of that event.

NOTE: The number of PAPI counters and their use can be overwhelming. Ratios derived from a combination of hardware events can sometimes provide more useful information than raw metrics. Develop the ability to interpret metric ratios with a focus on understanding:

- Instructions per cycle or cycles per instruction
- Floating point / Vectorization efficiency
- Cache behaviors; Long latency instruction impact
- Branch mispredictions
- Memory and resource access patterns
- Pipeline stalls

4.1 Hardware Counter Experiment (hwc)

As an example we will run the osshwc experiment on our test program smg2000. The convenience script for this is experiment is:

```
> osshwc “mpirun –np 256 smg2000 –n 50 50 50” <counter> <threshold>
```

This is the same syntax as the osshwctime experiment. Note that if your output is empty, try lowering the <threshold> value, it is calculated by O|SS by default. You can try lowering the threshold value if there have not been enough PAPI event occurrences to record. Also see the HINT in the osshwcsamp section above. You can run osshwcsamp and use a formula to create a reasonable threshold. Any counter reported by “papi_avail –a” that is not derived is available for use. You can also see the available counters by using the osshwc or osshwctime commands with no arguments. Native counters are listed in the PAPI documentation.

PAPI Name	Description	Threshold
PAPI_L1_DCM	L1 data cache misses	high
PAPI_L2_DCM	L2 data cache misses	high/medium
PAPI_L1_DCA	L1 data cache accesses	high
PAPI_FPU_IDL	Cycles in which FPUs are idle	high/medium
PAPI_STL_ICY	Cycles with no instruction issue	high/medium
PAPI_BR_MSP	Miss-predicted branches	medium/low
PAPI_FP_INS	Number of floating point instructions	high
PAPI_LD_INS	Number of load instructions	high
PAPI_VEC_INS	Number of vector/SIMD instructions	high/medium
PAPI_HW_INT	Number of hardware interrupts	low
PAPI_TLB_TL	Number of TLB misses	low

Note the Threshold indications are just for rough guidance and are dependent on the application. Also remember that not all counters will exist on all platforms, run osshwc with no arguments to see the available hardware counters available.

In the sections below, we show the outputs from the osshwc experiment, note that the default counter is the total cycles.

4.1.1 Hardware Counter Threshold (hwc) experiment performance data gathering

The hardware counter threshold experiment convenience script is "osshwc". Use this convenience script in this manner to gather counter values for one unique hardware counter:

```
osshwc "how you normally run your application" <papi event > < threshold value>
```

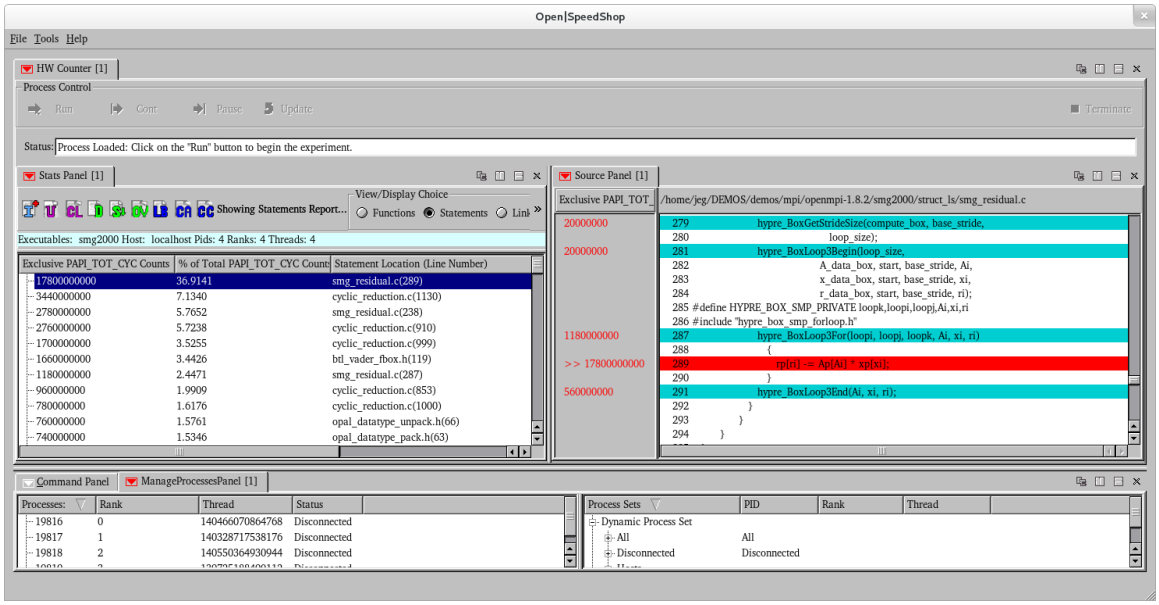
The following is an example of how to gather data for the smg2000 application on a Linux cluster platform using the osshwc convenience script. It gathers performance data for the default counter, PAPI_TOT_CYC because there is no hardware counter value specified after the quoted application run command.

```
osshwc "mpirun -np 4 ./smg2000 -n 60 60 60"
```

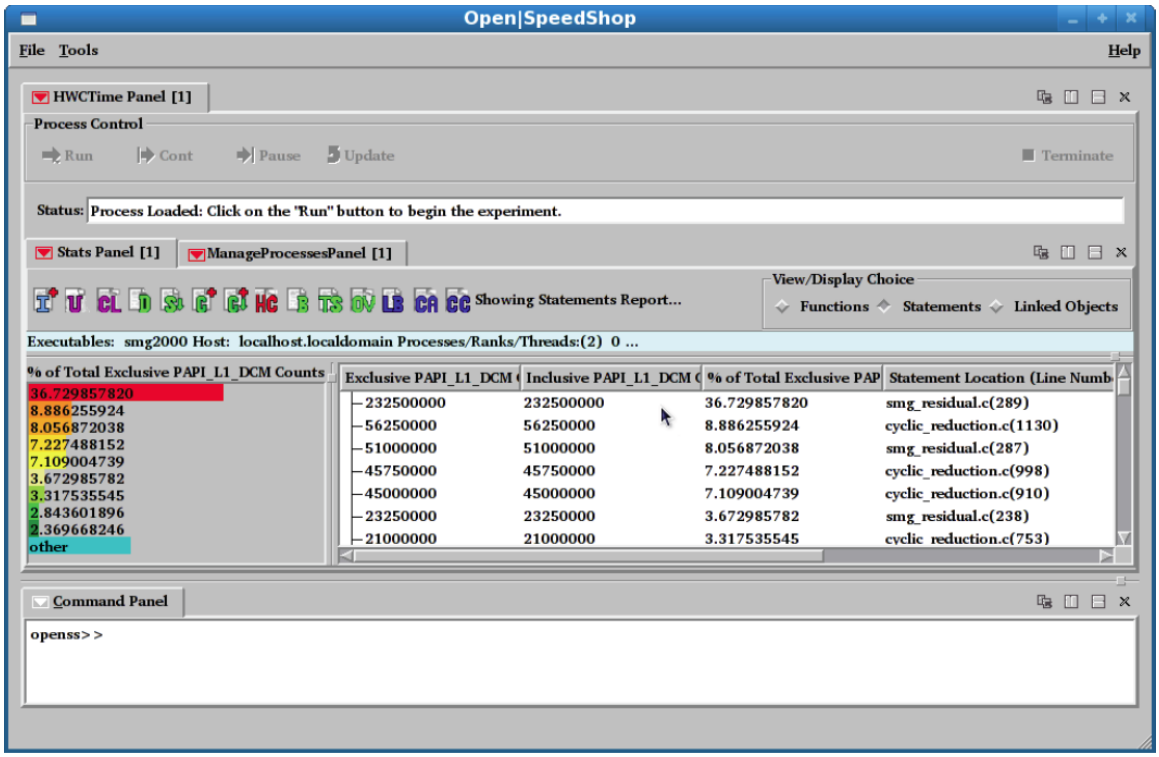
4.1.2 Hardware Counter Threshold (hwc) experiment performance data viewing with GUI

To launch the GUI on any experiment, use "openss –f <database name>".

This image shows the default view for the hwc experiment run with the smg2000 MPI application using PAPI_TOT_CYC as the hardware counter event. Double clicking on a line in the Stats Panel or on the bar chart will take the user to the source file and line represented by that line of performance information.



The next image displays the output from the osshwctime experiment where the counter is the L1 cache misses.



4.1.3 Hardware Counter Threshold (hwc) experiment performance data viewing with CLI

To launch the CLI on any experiment, use "openss –cli –f <database name>".
In this example we show three view default CLI views with different granularities: function, statement, and library level.

```
openss -f smg2000-hwc-3.openss
[openss]: The restored experiment identifier is:  -x 1

[jeg@localhost test]$ openss -cli -f smg2000-hwc-3.openss
openss>>[openss]: The restored experiment identifier is:  -x 1
openss>>expview
  Exclusive          % of Total         Function (defining location)
PAPI_TOT_CYC    PAPI_TOT_CYC
    Counts           Counts
23080000000      43.8283    hypre_SMGResidual (smg2000: smg_residual.c,152)
12880000000      24.4588    hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
 3540000000       6.7224    mca_btl_vader_check_fboxes (libmpi.so.1.5.2: btl_vader_fbox.h,106)
 1420000000       2.6965    unpack_predefined_data (libopen-pal.so.6.2.0: opal_datatype_unpack.h,41)
 1220000000       2.3167    hypre_SemiInterp (smg2000: semi_interp.c,126)
 1140000000       2.1648    pack_predefined_data (libopen-pal.so.6.2.0: opal_datatype_pack.h,38)
 1020000000       1.9370    __memcpy_ssse3_back (libc-2.17.so)
  740000000       1.4052    hypre_SemiRestrict (smg2000: semi_restrict.c,125)
 …
 …


openss>>expview -v statements

  Exclusive          % of Total     Statement Location (Line Number)
PAPI_TOT_CYC    PAPI_TOT_CYC
    Counts           Counts
17800000000      36.9141    smg_residual.c(289)
 3440000000       7.1340    cyclic_reduction.c(1130)
 2780000000       5.7652    smg_residual.c(238)
 2760000000       5.7238    cyclic_reduction.c(910)
 1700000000       3.5255    cyclic_reduction.c(999)
 1660000000       3.4426    btl_vader_fbox.h(119)
 1180000000       2.4471    smg_residual.c(287)
  960000000       1.9909    cyclic_reduction.c(853)
…
…

openss>>expview -v linkedobjects

  Exclusive          % of Total       LinkedObject
PAPI_TOT_CYC    PAPI_TOT_CYC
    Counts           Counts
40800000000      77.3606      smg2000
 6060000000      11.4903      libmpi.so.1.5.2
 4160000000       7.8878      libopen-pal.so.6.2.0
 1720000000       3.2613      libc-2.17.so
```

4.2 Hardware Counter Time Experiment (hwctime)

As an example we will run the osshwc experiment on our test program smg2000. The convenience script for this is experiment is:

```
> osshwctime "mpirun –np 256 smg2000 –n 50 50 50" <counter> <threshold>
```

This is the same syntax as the osshwc experiment. Note that if your output is empty, try lowering the <threshold> value, it is calculated by O|SS by default. You can try lowering the threshold value if there have not been enough PAPI event occurrences to record. Also see the HINT in the osshwcsamp section below. You can run osshwcsamp and use a formula to create a reasonable threshold. Any counter reported by "papi_avail –a" that is not derived is available for use. You can also see the available counters by using the osshwc or osshwctime commands with no arguments. Native counters are listed in the PAPI documentation.

PAPI Name	Description	Threshold
PAPI_L1_DCM	L1 data cache misses	high
PAPI_L2_DCM	L2 data cache misses	high/medium
PAPI_L1_DCA	L1 data cache accesses	high
PAPI_FPU_IDL	Cycles in which FPUs are idle	high/medium
PAPI_STL_ICY	Cycles with no instruction issue	high/medium
PAPI_BR_MSP	Miss-predicted branches	medium/low
PAPI_FP_INS	Number of floating point instructions	high
PAPI_LD_INS	Number of load instructions	high
PAPI_VEC_INS	Number of vector/SIMD instructions	high/medium
PAPI_HW_INT	Number of hardware interrupts	low
PAPI_TLB_TL	Number of TLB misses	low

Note the Threshold indications are just for rough guidance and are dependent on the application. Also remember that not all counters will exist on all platforms, run osshwc with no arguments to see the available hardware counters available.

In the sections below, we show the outputs from the osshwctime experiment, note that the default counter is the total cycles.

4.2.1 Hardware Counter Time Threshold (hwctime) experiment performance data gathering

The hardware counter threshold experiment convenience script is “osshwc”. Use this convenience script in this manner to gather counter values for one unique hardware counter:

```
osshwctime “how you normally run your application” <papi event > < threshold value>
```

The following is an example of how to gather data for the smg2000 application on a Linux cluster platform using the osshwc convenience script. The osshwctime convenience script will gather performance data for the default counter, PAPI_TOT_CYC if there is no hardware counter value specified after the quoted application run command. In our example, we specify an alternative counter, PAPI_L1_DCM and a specific threshold value, 750000. Each time the threshold value is reached, a sample will be taken and recorded. At program completion, an O|SS database file is created and the performance data can be viewed. A default report is shown as part of the O|SS convenience script (see below).

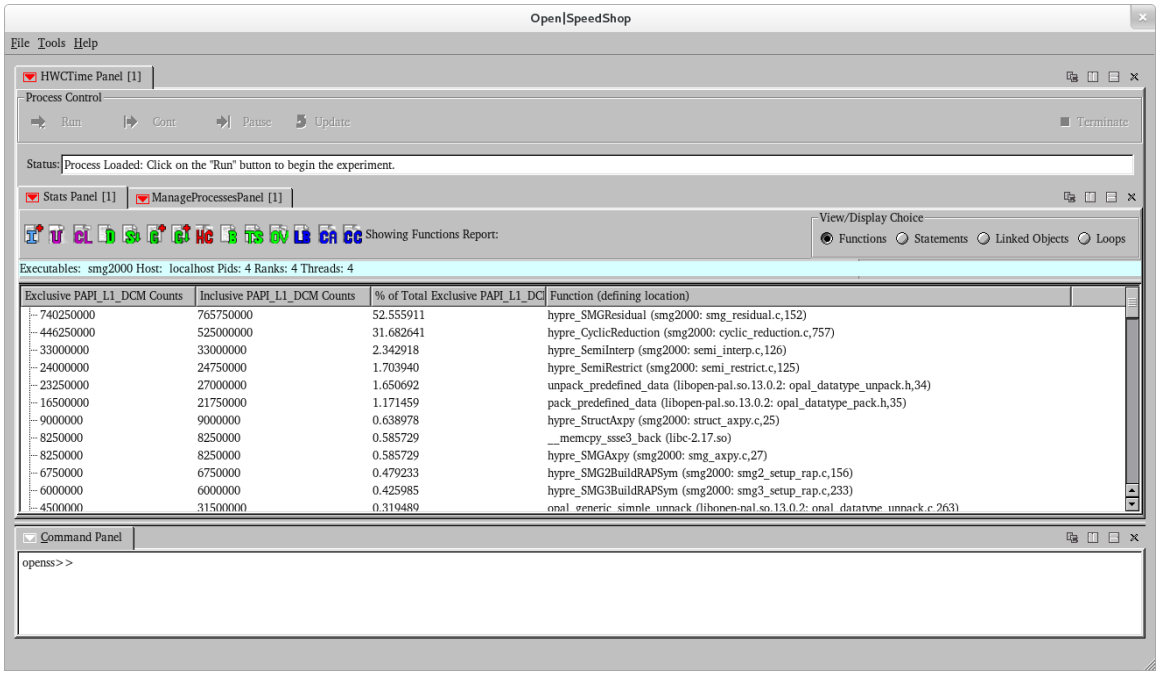
```
$ osshwctime "mpirun -np 4 ./smg2000 -n 65 65 65" PAPI_L1_DCM 750000
[openss]: hwctime using default threshold: 750000.
[openss]: hwctime using user specified papi event: "PAPI_L1_DCM"
Creating topology file for frontend host localhost
Generated topology file: ./cbtfAutoTopology
Running hwctime collector.
Program: mpirun -np 4 ./smg2000 -n 65 65 65
Number of mrnet backends: 4
Topology file used: ./cbtfAutoTopology
executing mpi program: mpirun -np 4  cbtfrun  --mpi  --mrnet  -c hwctime ./smg2000 -n 65
65 65
Running with these driver parameters:
  (nx, ny, nz)    = (65, 65, 65)
  (Px, Py, Pz)    = (4, 1, 1)
  (bx, by, bz)    = (1, 1, 1)
  (cx, cy, cz)    = (1.000000, 1.000000, 1.000000)
  (n_pre, n_post) = (1, 1)
  dim             = 3
  solver ID       = 0
=============================================
Struct Interface:
=============================================
Struct Interface:
  wall clock time = 0.024858 seconds
  cpu clock time  = 0.030000 seconds
=============================================
Setup phase times:
=============================================
SMG Setup:
  wall clock time = 0.624002 seconds
  cpu clock time  = 0.620000 seconds
```

```
=========================================
Solve phase times:
=========================================
SMG Solve:
  wall clock time = 3.907005 seconds
  cpu clock time  = 3.870000 seconds

Iterations = 7
Final Relative Residual Norm = 1.760588e-07

All Threads are finished.
default view for ./smg2000-hwctime-4.openss
[openss]: The restored experiment identifier is:  -x 1
Performance data spans 4.818158 seconds  from 2016/11/11 11:12:31 to 2016/11/11
11:12:36

  Exclusive    Inclusive   % of Total  Function (defining location)
PAPI_L1_DCM  PAPI_L1_DCM    Exclusive
    Counts       Counts  PAPI_L1_DCM
                    Counts
  740250000    765750000    52.555911  hypre_SMGResidual (smg2000: smg_residual.c,152)
  446250000    525000000    31.682641  hypre_CyclicReduction (smg2000:
cyclic_reduction.c,757)
   33000000     33000000     2.342918  hypre_SemiInterp (smg2000: semi_interp.c,126)
   24000000     24750000     1.703940  hypre_SemiRestrict (smg2000: semi_restrict.c,125)
   23250000     27000000     1.650692  unpack_predefined_data (libopen-pal.so.13.0.2:
opal_datatype_unpack.h,34)
   16500000     21750000     1.171459  pack_predefined_data (libopen-pal.so.13.0.2:
opal_datatype_pack.h,35)
    9000000      9000000     0.638978  hypre_StructAxpy (smg2000: struct_axpy.c,25)
    8250000      8250000     0.585729  hypre_SMGAxpy (smg2000: smg_axpy.c,27)
    8250000      8250000     0.585729  __memcpy_ssse3_back (libc-2.17.so)
    6750000      6750000     0.479233  hypre_SMG2BuildRAPSym (smg2000:
smg2_setup_rap.c,156)
    6000000      6000000     0.425985  hypre_SMG3BuildRAPSym (smg2000:
smg3_setup_rap.c,233)
```

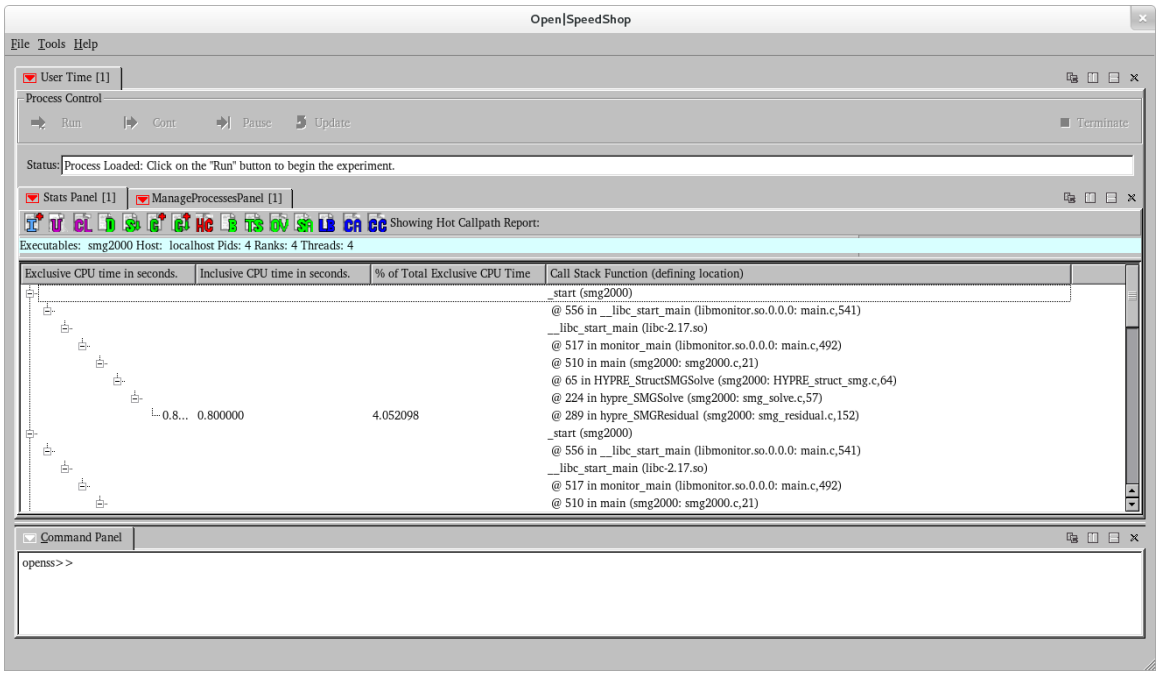
4.2.2 Hardware Counter Threshold (hwctime) experiment performance data viewing with GUI

To launch the GUI on any experiment, use "openss –f <database name>".

This image shows the default view for the hwc experiment run with the smg2000 MPI application using PAPI_L1_DCM as the hardware counter event. Double clicking on a line in the Stats Panel or on the bar chart will take the user to the source file and line represented by that line of performance information.

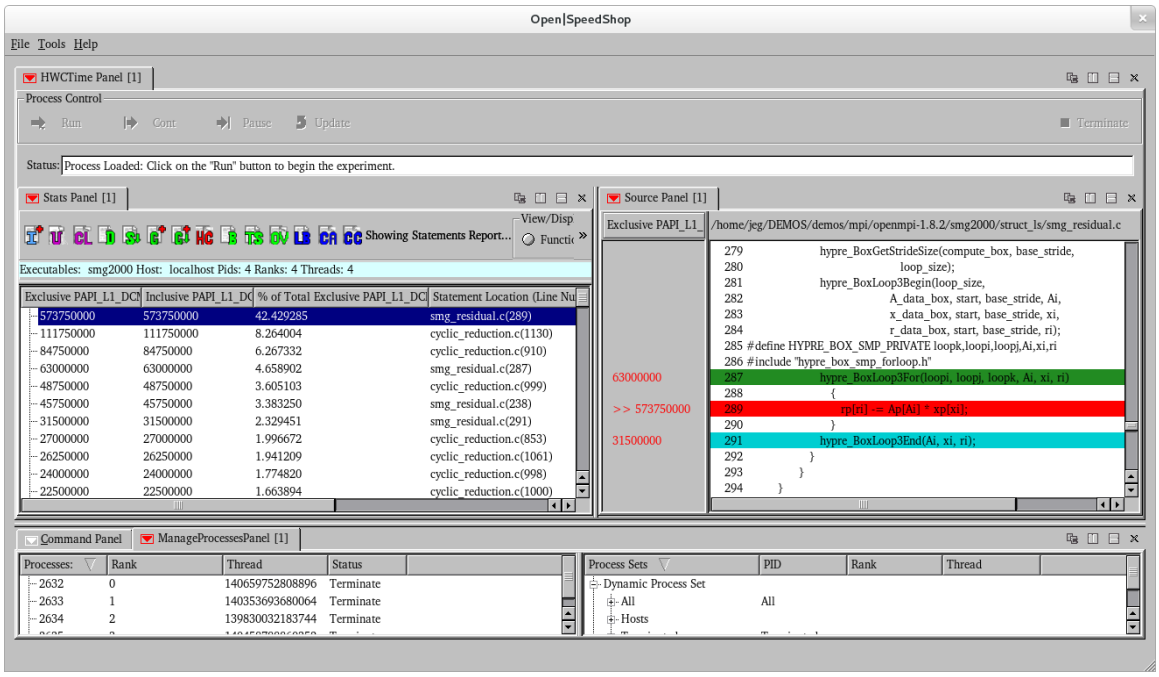


The next image displays the output from the osshwctime experiment where the Hot Call Path icon (HC in red) was chosen. This displays the top 5 time taking call paths in the smg2000 application.



The view below shows the top time taking statements and the source panel focused on the statement in smg2000 that took the most time. Double clicking on the

statistics lines in the StatsPanel will focus the source panel on the source line corresponding to the statistics line.



4.2.3 Hardware Counter Time Threshold (hwctime) experiment performance data viewing with CLI

To launch the CLI on any experiment, use “openss –cli –f <database name>“.
In this example we show three view default CLI views with different granularities: function, statement, and library level.

This is the CLI default view for the hwctime experiment.

```
[jeg@localhost test]$ openss -cli -f smg2000-hwctime-4.openss
openss>>[openss]: The restored experiment identifier is:  -x 1
openss>>expview hwctime10

  Exclusive    Inclusive   % of Total  Function (defining location)
PAPI_L1_DCM  PAPI_L1_DCM    Exclusive
    Counts       Counts  PAPI_L1_DCM
                           Counts
 740250000    765750000    52.555911  hypre_SMGResidual (smg2000: smg_residual.c,152)
 446250000    525000000    31.682641  hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
  33000000     33000000     2.342918  hypre_SemiInterp (smg2000: semi_interp.c,126)
  24000000     24750000     1.703940  hypre_SemiRestrict (smg2000: semi_restrict.c,125)
  23250000     27000000     1.650692  unpack_predefined_data (libopen-pal.so.13.0.2:
opal_datatype_unpack.h,34)
  16500000     21750000     1.171459  pack_predefined_data (libopen-pal.so.13.0.2:
opal_datatype_pack.h,35)
   9000000      9000000     0.638978  hypre_StructAxpy (smg2000: struct_axpy.c,25)
   8250000      8250000     0.585729  hypre_SMGAxpy (smg2000: smg_axpy.c,27)
```

```
  8250000     8250000    0.585729  __memcpy_ssse3_back (libc-2.17.so)
  6750000     6750000    0.479233  hypre_SMG2BuildRAPSym (smg2000: smg2_setup_rap.c,156)
```

This is the CLI view for the hwctime experiment showing the performance information based on the loops in smg2000.

```
open ss>>expview -v loops hwctime10
 Exclusive    Inclusive   % of Total  Loop Start Location (Line Number)
PAPI_L1_DCM  PAPI_L1_DCM    Exclusive
   Counts      Counts  PAPI_L1_DCM
                 Counts
 739500000   765000000    42.813721  smg_residual.c(204)
 213000000   256500000    12.331741  cyclic_reduction.c(882)
 192000000   227250000    11.115936  cyclic_reduction.c(1022)
  41250000    41250000     2.388189  cyclic_reduction.c(851)
  41250000    41250000     2.388189  cyclic_reduction.c(835)
  40500000    40500000     2.344768  cyclic_reduction.c(851)
  39000000    39000000     2.257924  cyclic_reduction.c(851)
  24000000    24750000     1.389492  semi_restrict.c(198)
  20250000    20250000     1.172384  semi_interp.c(292)
  20250000    20250000     1.172384  semi_interp.c(292)
```

This is the CLI view for the hwctime experiment showing the performance information based on the statements in smg2000. Statement 289 in smg2000 had the most level 1 data cache misses during this particular experiment.

```
openss>>expview -vstatements hwctime10

 Exclusive    Inclusive   % of Total  Statement Location (Line Number)
PAPI_L1_DCM  PAPI_L1_DCM    Exclusive
   Counts      Counts  PAPI_L1_DCM
                 Counts
 573750000   573750000    42.429285  smg_residual.c(289)
 111750000   111750000     8.264004  cyclic_reduction.c(1130)
  84750000    84750000     6.267332  cyclic_reduction.c(910)
  63000000    63000000     4.658902  smg_residual.c(287)
  48750000    48750000     3.605103  cyclic_reduction.c(999)
  45750000    45750000     3.383250  smg_residual.c(238)
  31500000    31500000     2.329451  smg_residual.c(291)
  27000000    27000000     1.996672  cyclic_reduction.c(853)
  26250000    26250000     1.941209  cyclic_reduction.c(1061)
  24000000    24000000     1.774820  cyclic_reduction.c(998)
```

This is the CLI view for the hwctime experiment showing the performance information based on the libraries or linked objects in smg2000. The smg2000 executable had 92% of the level 1 data cache misses during this particular experiment.

```
openss>>expview -v linkedobjects

 Exclusive    Inclusive   % of Total  LinkedObject
PAPI_L1_DCM  PAPI_L1_DCM    Exclusive
   Counts      Counts  PAPI_L1_DCM
```

	Counts		
1297500000	1410000000	92.021277	smg2000
58500000	81750000	4.148936	libopen-pal.so.13.0.2
34500000	101250000	2.446809	libmpi.so.12.0.2
19500000	1410000000	1.382979	libc-2.17.so

4.3 Hardware Counter Sampling (hwcsamp) Experiment

The osshwcsamp experiment supports both derived and non-derived PAPI presets and is able to sample up to six counters at one time. Again you can check the available counters by running osshwcsamp with no arguments. All native events are available including architecture specific events listed in the PAPI documentation. Native events are also reported by papi_native_avail.

The hardware counter sampling experiment uses a sampling rate (instead of the threshold used in the previous experiments). But like the threshold, the sampling rate is depended on the application and must be balanced between overhead and accuracy. In this case the lower the sampling rate the less samples recorded.

The convenience script for this is experiment is:

```
> osshwcsamp "mpirun –np 256 smg2000 –n 50 50 50" <event_list> <sampling_rate>
```

Note if a counter does not appear in the output, there may be a conflict in the hardware counters. To find conflicts use

```
> papi_event_chooser PRESET <list_of_events>
```

Here is a list of some possible hardware counter combinations to use (list provided by Koushik Ghosh, LLNL).

For **Xeon** processors:	
PAPI_FP_INS, PAPI_LD_INS, PAPI_SR_INS	Load store info, memory bandwidth needs
PAPI_L1_DCM, PAPI_L1_TCA	L1 cache hit/miss ratios
PAPI_L2_DCM, PAPI_L2_TCA	L2 cache hit/miss ratios
LAST_LEVEL_CACHE_MISSES, LAST_LEVEL_CACHE_REFERENCES	L3 cache info
MEM_UNCORE_RETIRED:REMOTE_DRAM, MEM_UNCORE_RETIRED:LOCAL_DRAM	Local/nonlocal memory access
For **Opteron** processors:	
PAPI_FAD_INS, PAPI_FML_INS	Floating point add multiply
PAPI_FDV_INS, PAPI_FSQ_INS	Square root and divisions
PAPI_DP_OPS, PAPI_VEC_INS	Floating point and vector instructions
READ_REQUEST_TO_L3_CACHE:ALL_CORES, L3_CACHE_MISSES:ALL_CORES	L3 cache

When selecting PAPI events you must determine if they are a valid combination. In general combination that are valid will pass the test:

```
> papi_event_chooser PRESET event1 event2 … eventN
```

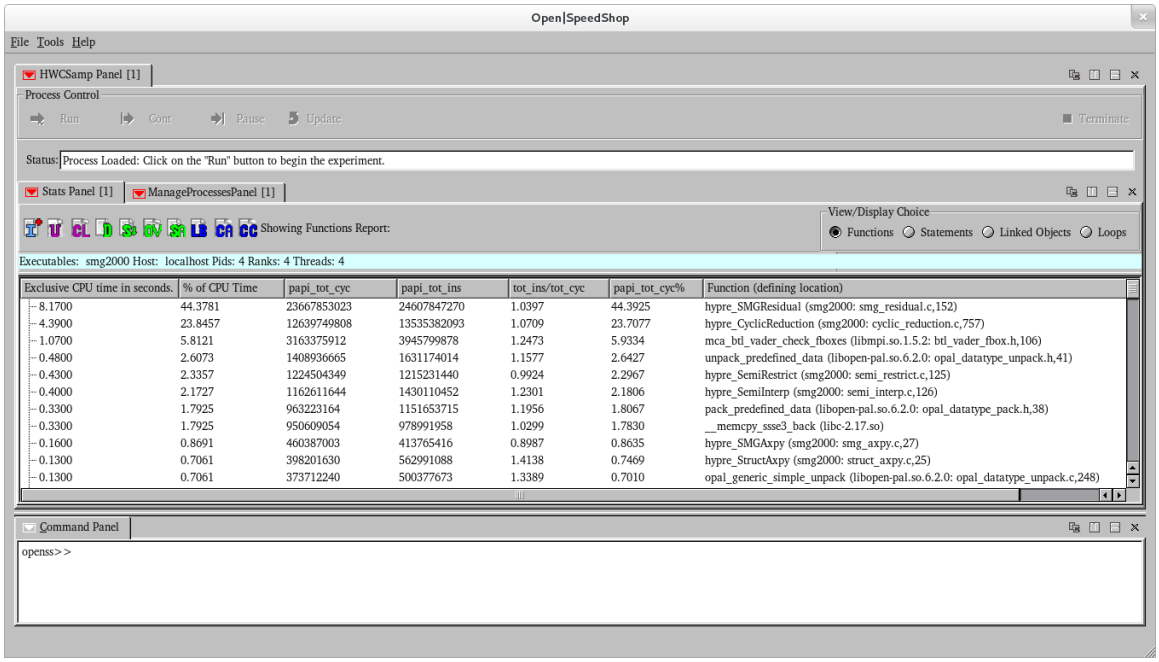
The output for a valid combination will contain:

```
event_chooser.c                 PASSED
```

Here is an example using PAPI to check if a three-event combination is valid.

```
> papi_event_chooser PRESET PAPI_FP_INS PAPI_LD_INS PAPI_SR_INS
--------------------------------------------------------------------------------PAPI Version             :4.1.2.1
Vendor string and code        : GenuineIntel (1)
Model string and code         : Intel Nehalem (21)
CPU Revision          : 5.000000
…
…
PAPI_VEC_SP 0x80000069 No Single precision vector/SIMD instructions
PAPI_VEC_DP 0x8000006a No Double precision vector/SIMD instructions
--------------------------------------------------------------------------------Total events reported: 44
event_chooser.c                 PASSED
```

Below shows the output of the osshwcsamp experiment with the counters for Total Cycles and Floating Point Operations.



Remember that you do not always need to use the O|SS GUI to examine the output of experiments, you can also use the command line interface to view all of the same information. For example, the same output from above can be seen on the command line:

```
>openss -cli -f smg2000-hwcsamp.openss
openss>>[openss]: The restored experiment identifier is:  -x 1
```

```
openss>>expview
Exclusive  % of CPU   papi_tot_cyc     papi_tot_ins     tot_ins/tot_cyc   papi_tot_cyc%  Function (defining location)
CPU time    Time                                            IPC
 8.1700   44.3781   23667853023  24607847270    1.0397   44.3925  hypre_SMGResidual (smg2000: smg_residual.c,152)
 4.3900   23.8457   12639749808  13535382093    1.0709   23.7077  hypre_CyclicReduction (smg2000:
cyclic_reduction.c,757)
 1.0700    5.8121    3163375912   3945799878    1.2473    5.9334  mca_btl_vader_check_fboxes (libmpi.so.1.5.2:
btl_vader_fbox.h,106)
 0.4800    2.6073    1408936665   1631174014    1.1577    2.6427  unpack_predefined_data (libopen-pal.so.6.2.0:
opal_datatype_unpack.h,41)
 0.4300    2.3357    1224504349   1215231440    0.9924    2.2967  hypre_SemiRestrict (smg2000: semi_restrict.c,125)
 0.4000    2.1727    1162611644   1430110452    1.2301    2.1806  hypre_SemiInterp (smg2000: semi_interp.c,126)

openss>>expview -v linkedobjects

Exclusive  % of CPU     papi_tot_cyc     papi_tot_ins  tot_ins/tot_cyc papi_tot_cyc%  LinkedObject
CPU time    Time                                            IPC
14.4400    78.3931   41735382047   44436967182       1.0647   78.2394  smg2000
 1.9400    10.5320    5687487004    7106186325       1.2494   10.6621  libmpi.so.1.5.2
 1.3400     7.2747    3918861297    4788179789       1.2218    7.3465  libopen-pal.so.6.2.0
 0.6700     3.6374    1918417268    2138815631       1.1149    3.5964  libc-2.17.so
 0.0300     0.1629      83014429      77541115       0.9341    0.1556  libpthread-2.17.so
18.4200   100.0000   53343162045   58547690042       1.0976  100.0000  Report Summary
```

4.3.1 Hardware Counter Sampling (hwcsamp) experiment performance data gathering

The hardware counter sampling experiment convenience script is "osshwcsamp". Use this convenience script in this manner to gather counter values for unique up to six (6) hardware counters:

```
osshwcsamp "how you normally run your application" <papi event list> < sampling rate>
```

4.3.1.1 Hardware Counter Sampling (hwcsamp) experiment parameters

The hwcsamp experiment is timer based not threshold based. What that means is a timer is used to periodically interrupt the processor. For the hwcsamp experiment, each time the timer interrupts the processor; the values of the hardware counter events specified will be read up and reset to 0 for the next timer cycle. This is repeated until the program finishes. O|SS allows the user to control the sampling rate.

The following is an example of how to gather data for the smg2000 application on a Linux cluster platform using the osshwcsamp convenience script and specifying a specific set of PAPI hwc events. In the next example the user is choosing to only sample 45 times a second instead of the default 100 times a second. Why would you want to do this? One reason would be to save database size, a lower sampling rate may give an accurate portrayal of the application behavior.

```
> osshwcsamp "mpirun –np 256 smg2000 –n 50 50 50" PAPI_L1_DCM,PAPI_L2_DCA,PAPI_L2_DCM,PAPI_L3_DCA,PAPI_L3_TCM
```

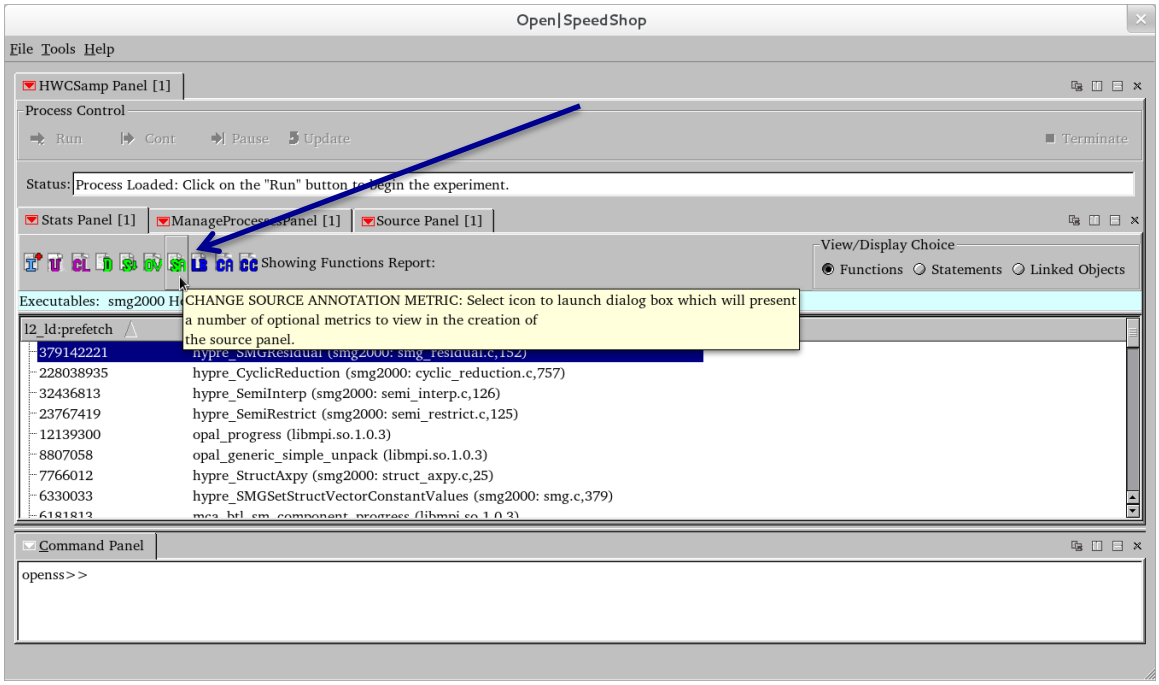
```
> osshwcsamp "mpirun –np 256 smg2000 –n 50 50 50" PAPI_L1_DCM,PAPI_L2_DCA,PAPI_L2_DCM 45
```

4.3.2 Hardware Counter Sampling (hwcsamp) experiment performance data viewing with GUI

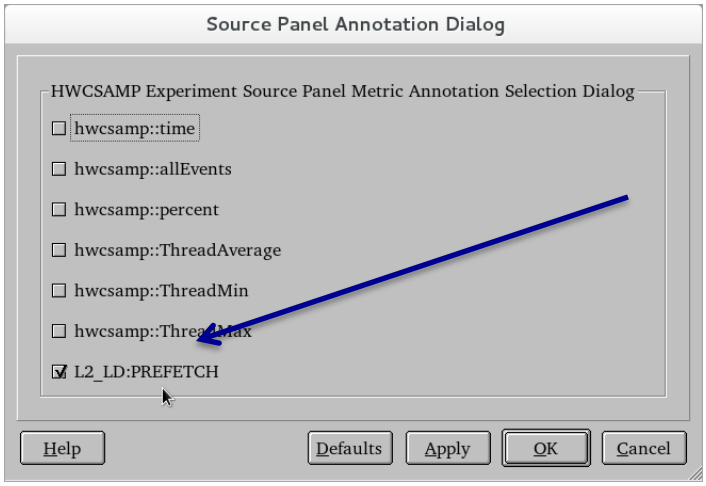
To launch the GUI on any experiment, use “openss –f <database name>“.

4.3.2.1 Getting the PAPI counter as the GUIs Source Annotation Metric

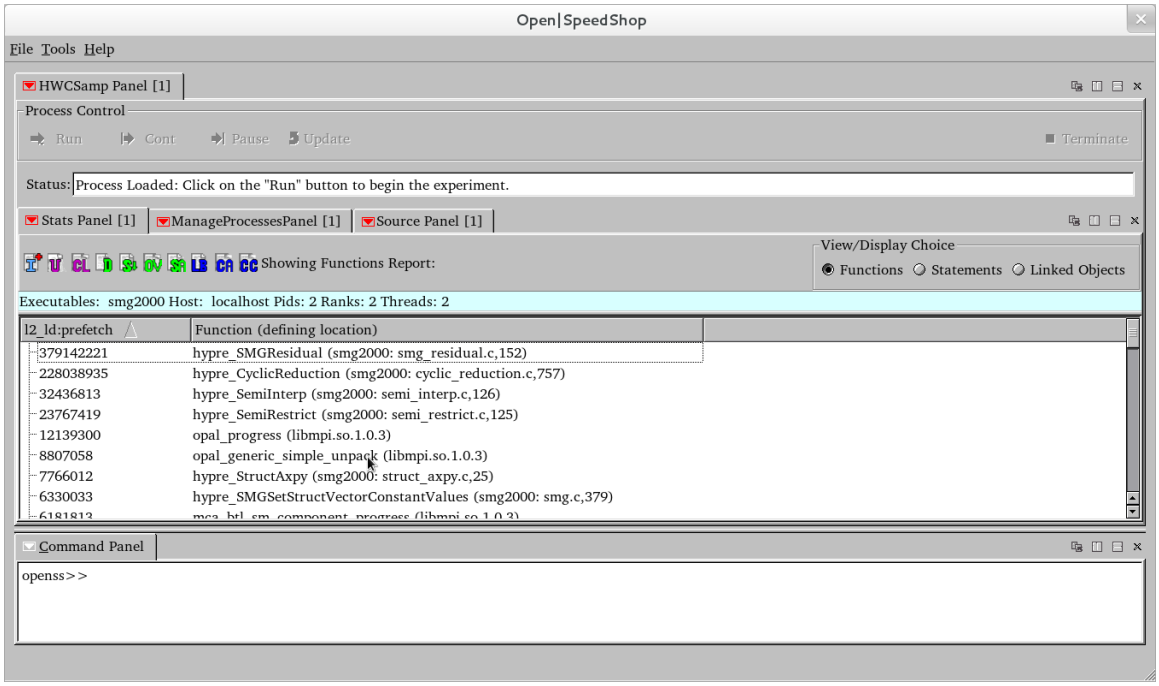
In order to make one of the PAPI or native hardware counters the counter that will show up in the source view, one can click on the “SA” icon, which represents Source Annotation. This brings up an option dialogue that allows you to choose the source annotation metric.



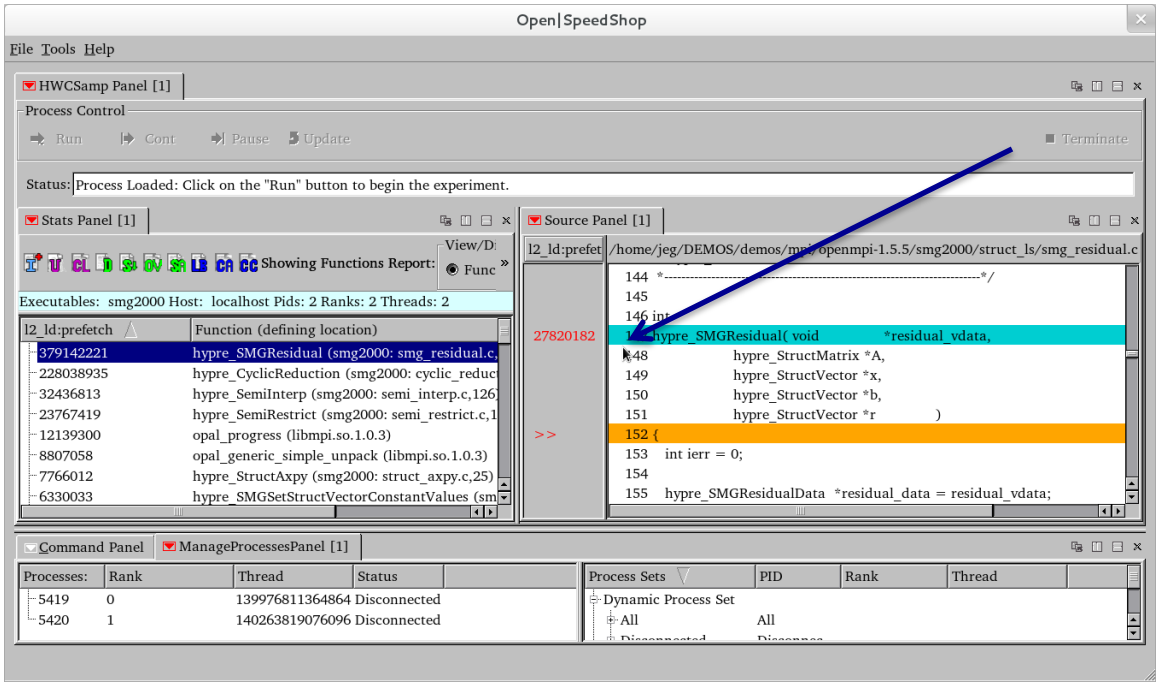
In this example the native counter we want to choose is L2_LD_PREFETCH. When we click to choose that counter and click on “OK” the Stats Panel view will regenerate and the source annotation metric will become L2_LD_PREFETCH.



The regenerated view now shows the results for only L2_LD:PREFETCH.



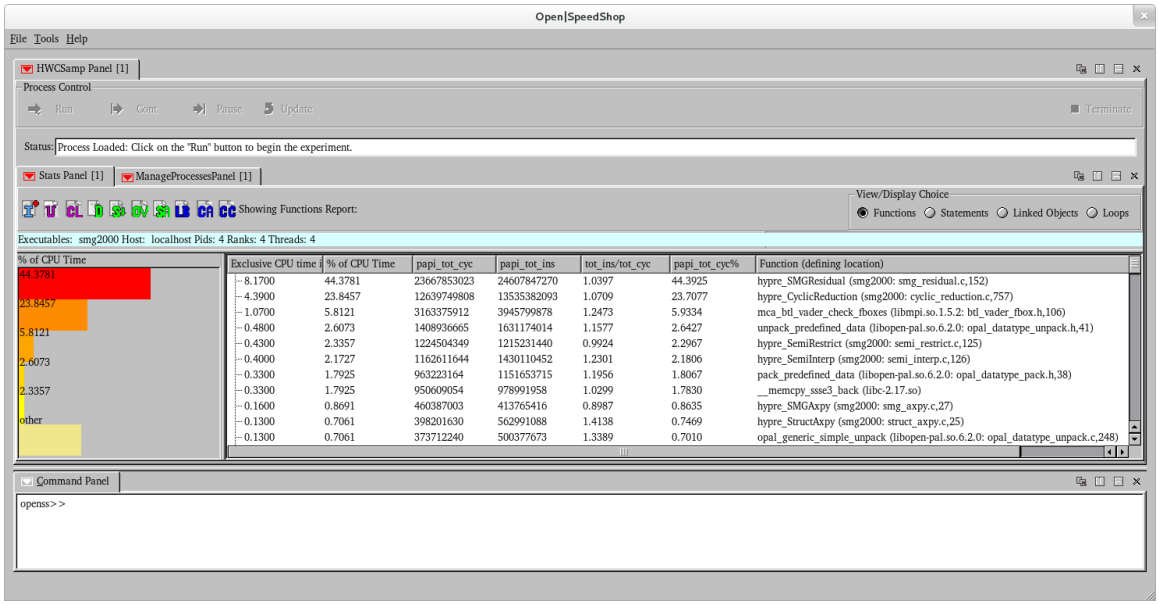
Now double clicking on the Stats Panel result line of choice will focus the source panel and use the PAPI or native counter that was chosen by using the Source Annotation dialog.



4.3.2.2 Viewing Hardware Counter Sampling Data with the GUI

To launch the GUI on any experiment, use “openss –f <database name>“.

The GUI view below represents an example of the default view for the hardware counter sampling (hwcsamp) experiment. In the default view the first set of performance data shown is program counter exclusive time (where the program is statistically spending its time) and the percentage of time spent in each function of the program. The next information is the hardware counter event counts listed in columns by the hardware counter event. Column three represents the counts that were recorded for PAPI_TOT_CYC and column four represents the counts for PAPI_TOT_INS. What this view can indicate to the viewer is whether or not the specified hardware counter events are occurring and if they are, then how prevalent are they. With this information the user could isolate down to see exactly where a particular event is occurring by using the hwc or hwctime experiment. These two experiments are threshold based. Which ultimately means you can map the performance data back to the source because the actual event triggered the recording of the counts of the event. This hwcsamp experiment is timer based, so O|SS cannot take you to the line of source exactly where the hardware counter events are happening. hwcsamp is an overview experiment that tells the user which events are occurring and if they are occurring in numbers that would warrant using the hwc or hwctime experiment to pinpoint where in the source the specified hardware counter event is actually occurring.



4.3.3 Hardware Counter Sampling (hwcsamp) experiment CLI performance data viewing

To launch the CLI on any experiment, use "openss –cli –f <database name>". The following example was run on the Yellowstone platform at NCAR/UCAR using the job script shown below.

4.3.3.1 Job Script and osshwcsamp command

```
#!/bin/csh
#
# LSF batch script to run an MPI application
#
#BSUB -P Pnnnnnnnn          # project code
#BSUB -W 00:30              # wall-clock time (hrs:mins)
#BSUB -n 64                 # number of tasks in job
#BSUB -R "span[ptile=4]"    # run 4 MPI tasks per node
#BSUB -J sweep3d-hwcsamp            # job name
#BSUB -o sweep3d-hwcsamp.%J.out     # output file name in which %J is replaced by the job ID
#BSUB -e sweep3d-hwcsamp.%J.err     # error file name in which %J is replaced by the job ID
#BSUB -q regular            # queue

module load openspeedshop

mkdir -p /glade/scratch/${USER}/sweep3d
rm -rf /glade/scratch/${USER}/sweep3d/hwcsamp
mkdir /glade/scratch/${USER}/sweep3d/hwcsamp
setenv OPENSS_RAWDATA_DIR /glade/scratch/${USER}/sweep3d/hwcsamp

setenv REQUEST_SUSPEND_HPC_STAT 1

echo "running (on compute node): osshwcsamp"
osshwcsamp "mpirun.lsf /glade/u/home/galaro/demos/sweep3d/orig/sweep3d.mpi"
PAPI_L1_DCM,PAPI_L1_ICM,PAPI_L1_TCM,PAPI_L1_LDM,PAPI_L1_STM
```

4.3.3.2 osshwcsamp experiment default CLI view

The table below describes information that is included in the hwcsamp experiment default view when no alternative PAPI hardware counter arguments are specified for the osshwcsamp experiment.

Column Name	Column Definition
Exclusive CPU Time	Aggregated total exclusive time spent in the application function corresponding to this row of data.
% of CPU Time	Percentage of exclusive time spent in the function corresponding to this row of data relative to the total application exclusive time for all the application functions.
PAPI_TOT_CYC	Number of hardware events corresponding to the hardware independent PAPI_TOT_CYC PAPI event. This value is based on reading the hardware counter event buffers based on sampling. This means this data may not accurately reflect where in the source these events occurred. It is an approximation of what is going in the application, but not a mapping back to the source lines. Use the hwc and hwctime experiments for that.
PAPI_TOT_INS	Number of hardware events corresponding to the hardware independent PAPI_TOT_INS PAPI event. This value is based on reading the hardware counter event buffers based on sampling. This means this data may not accurately reflect where in the source these events occurred. It is an approximation of what is going in the application, but not a mapping back to the source lines. Use the hwc and hwctime experiments for that.
TOT_INS/TOT_CYC	This is the graduated instructions per cycle, which is the ratio between the approximation of the total number of instructions divided by the total number of cycles
% of TOT_CYC	The percentage of PAPI_TOT_CYC events for this function relative to the number of PAPI_TOT_CYC events that occurred in all the application functions.

This is a default CLI view for the hwcsamp experiment:

```
Exclusive  % of CPU  papi_tot_cyc  papi_tot_ins  tot_ins/tot_cyc papi_tot_cyc%  Function (defining location)
CPU time Time
in
seconds.
 74.0600   99.8786  177712237021   51989184616    0.2925     99.8787  main (nbody: nbody-mpi.c,71)
  0.0400    0.0539         95958566         28058948    0.2924      0.0539  fesetenv (libm-2.19.so)
  0.0300    0.0405         71987793         21053819    0.2925      0.0405  __sqrt_finite (libm-2.19.so)
  0.0100    0.0135         23864331          6996727    0.2932      0.0134  memcpy (libc-2.19.so)
  0.0100    0.0135         23995616          7018006    0.2925      0.0135  fegetround (libm-2.19.so)
 74.1500  100.0000  177928043327   52052312116    0.2925    100.0000  Report Summary
```

This is the output from an osshwcsamp experiment non-default experiment where PAPI_L1_DCM,PAPI_L1_ICM,PAPI_L1_TCM,PAPI_L1_LDM,PAPI_L1_STM were specified on the osshwcsamp command.

```
openss -cli -f L1-64PE-sweep3d.mpi-hwcsamp.openss
```

```
openss>>[openss]: The restored experiment identifier is:  -x 1
openss>>expview -v summary

 Exclusive    % of CPU  papi_l1_dcm  papi_l1_icm  papi_l1_tcm papi_l1_ldm  papi_l1_stm  Function (defining location)
CPU time in Time
seconds.
824.870000   38.689781    8646497071   117738843    8764235914    8396159476  196649065  __libc_poll (libc-2.12.so)
799.300000   37.490443  46691996441   367096209  47059092650 46247555479   281624221  sweep (sweep3d.mpi:
sweep.f,2)
  75.000000    3.517807     782716992    10680760     793397752     757322217    20159725
PAMI::Interface::Context<PAMI::Context>::advance (libpami.so: ContextInterface.h,158)
 55.750000     2.614903     597583047     8038242     605621289
579127274    14647999  LapiImpl::Context::Advance<true, true, false> (libpami.so: Context.h,220)
 52.970000    2.484510    550761926    7569975    558331901 535841812    11563657  __libc_enable_asynccancel (libc-
2.12.so)
 49.850000    2.338169    518605433    6979361    525584794 502551336    12757207  _lapi_dispatcher<false> (libpami.so:
lapi_dispatcher.c,57)
 48.080000    2.255149    488545916    6784192    495330108 476065093     9649598  LapiImpl::Context::TryLock<true, true,
false> (libpami.so: Context.h,198)
 47.750000    2.239671    479947719    6732551    486680270 471343480     6436257  __libc_disable_asynccancel (libc-
2.12.so)
 26.680000    1.251401    275998769    3888499    279887268 269841454     4697170  udp_read_callback (libpamiudp.so:
lapi_udp.c,538)
 25.880000    1.213878   1522697263    12118336   1534815599 1507685061     9619348  __intel_ssse3_rep_memcpy
(libirc.so)
 21.960000    1.030014    223197680    3086626    226284306 215787794     5879517  _lapi_shm_dispatcher (libpami.so:
lapi_shm.c,2283)
 14.910000    0.699340    154744623    2075688    156820311 149803306     3979337  LapiImpl::Context::CheckContext
(libpami.so: CheckParam.cpp,21)
 13.990000    0.656188    151052863    2000330    153053193 146967548     3167039  LapiImpl::Context::Unlock<true, true,
false> (libpami.so: Context.h,204)
```

4.3.3.2 osshwcsamp experiment Status command and CLI view

```
openss>>expstatus

  Experiment definition
{ # ExpId is 1, Status is NonExistent, Saved database is L1-64PE-sweep3d.mpi-hwcsamp.openss
   Performance data spans 1:7.958138 mm:ss  from 2013/03/27 22:32:45 to 2013/03/27 22:33:53
  Executables Involved:
         sweep3d.mpi
 Currently Specified Components:
   -h ys6128 -p 2765 -t 47176895393312 -r 3 (sweep3d.mpi)
   -h ys6128 -p 2766 -t 47824321252896 -r 0 (sweep3d.mpi)
   -h ys6128 -p 2767 -t 47369830317600 -r 1 (sweep3d.mpi)
   -h ys6128 -p 2768 -t 47378742910496 -r 2 (sweep3d.mpi)
   -h ys6129 -p 22862 -t 47327259860512 -r 5 (sweep3d.mpi)
   -h ys6129 -p 22863 -t 47201888194080 -r 6 (sweep3d.mpi)
   -h ys6129 -p 22864 -t 47185544437280 -r 7 (sweep3d.mpi)
   …
   -h ys6250 -p 11462 -t 47028080107040 -r 63 (sweep3d.mpi)
   -h ys6250 -p 11463 -t 47600632852000 -r 60 (sweep3d.mpi)
   -h ys6250 -p 11464 -t 47494028697120 -r 61 (sweep3d.mpi)
   -h ys6250 -p 11465 -t 47944527175200 -r 62 (sweep3d.mpi)
 Previously Used Data Collectors:
             hwcsamp
            Metrics:
  hwcsamp::exclusive_detail
      hwcsamp::percent
  hwcsamp::threadAverage
    hwcsamp::threadMax
    hwcsamp::threadMin
        hwcsamp::time
     Parameter Values:
  hwcsamp::event = PAPI_L1_DCM,PAPI_L1_ICM,PAPI_L1_TCM,PAPI_L1_LDM,PAPI_L1_STM
  hwcsamp::sampling_rate =  100
     Available Views:
```

```
        hwcsamp
          }
```

4.3.3.3 osshwcsamp experiment Load Balance command and CLI view

```
openss>>expview -m loadbalance

 Max CPU  Rank    Min CPU  Rank    Average  Function (defining location)
   Time    of      Time    of   CPU Time
  Across  Max     Across   Min     Across
Ranks(s)         Ranks(s)         Ranks(s)
14.890000    28  10.950000    27  12.888594  __libc_poll (libc-2.12.so)
14.270000    47  11.780000    51  12.489062  sweep (sweep3d.mpi: sweep.f,2)
1.620000    43   0.840000    37   1.171875 PAMI::Interface::Context<PAMI::Context>::advance (libpami.so:
ContextInterface.h,158)
1.320000    16   0.570000     3   0.871094 LapiImpl::Context::Advance<true, true, false> (libpami.so: Context.h,220)
1.130000    60   0.500000     2   0.778906 _lapi_dispatcher<false> (libpami.so: lapi_dispatcher.c,57)
1.110000    35   0.520000    49   0.751250 LapiImpl::Context::TryLock<true, true, false> (libpami.so: Context.h,198)
1.030000    42   0.600000    12   0.827656 __libc_enable_asynccancel (libc-2.12.so)
0.950000    62   0.520000    38   0.746094 __libc_disable_asynccancel (libc-2.12.so)
0.700000     6   0.200000    59   0.343125  _lapi_shm_dispatcher (libpami.so: lapi_shm.c,2283)
0.630000    33   0.250000     0   0.404375 __intel_ssse3_rep_memcpy (libirc.so)
0.600000    18   0.270000    16   0.416875  udp_read_callback (libpamiudp.so:
```

4.3.3.4 osshwcsamp experiment Linked Object command and CLI view

```
openss>>expview -v linkedobjects

 Exclusive    % of CPU  papi_l1_dcm  papi_l1_icm  papi_l1_tcm papi_l1_ldm  papi_l1_stm  LinkedObject
CPU time in Time
seconds.
 928.310000   43.541541   9818946796   133244862   9952191658   9543597734   215608918  libc-2.12.so
 811.920000   38.082373  47212355914   369525459  47581881373  46596204924   441601622  sweep3d.mpi
 311.490000   14.610157   3356646038    44875637   3401521675   3255300343    80090932  libpami.so
  29.640000    1.390237   1824778610    12931604   1837710214   1680978945   127174346  libirc.so
  26.930000    1.263127    287313329     3994016    291307345    281053971     4763152  libpamiudp.so
  22.250000    1.043616   1049603690     9037920   1058641610   1033650896    11422120  libpthread-2.12.so
   1.440000    0.067542     72649683      620083     73269766     71327993     1007704  libmpich.so.3.3
   0.020000    0.000938      1286256       23770      1310026      1232178        5222  ld-2.12.so
   0.010000    0.000469          327         394          721          313          13  librt-2.12.so
2132.010000  100.000000  63623580643   574253745  64197834388  62463347297   881674029  Report Summary
openss>>
```

4.3.3.5 osshwcsamp experiment only the hwcsamp PAPI events CLI view

The -m allEvents option prints only the PAPI event values and not the program counter sampling exclusive time and percentage values.

```
openss -cli -f L1-64PE-sweep3d.mpi-hwcsamp.openss
openss>>[openss]: The restored experiment identifier is:  -x 1
openss>>expview -m allEvents

 papi_l1_dcm  papi_l1_icm  papi_l1_tcm papi_l1_ldm  papi_l1_stm  Function (defining location)
 8646497071   117738843    8764235914   8396159476  196649065  __libc_poll (libc-2.12.so)
46691996441   367096209  47059092650 46247555479   281624221  sweep (sweep3d.mpi: sweep.f,2)
  782716992    10680760     793397752    757322217    20159725  PAMI::Interface::Context<PAMI::Context>::advance
  597583047     8038242     605621289    579127274    14647999  LapiImpl::Context::Advance<true, true, false>
  550761926     7569975     558331901    535841812    11563657  __libc_enable_asynccancel (libc-2.12.so)
  518605433     6979361     525584794    502551336    12757207  _lapi_dispatcher<false> (libpami.so:
lapi_dispatcher.c,57)
  488545916     6784192     495330108    476065093     9649598  LapiImpl::Context::TryLock<true, true, false>
  479947719     6732551     486680270    471343480     6436257  __libc_disable_asynccancel (libc-2.12.so)
  275998769     3888499     279887268    269841454     4697170  udp_read_callback (libpamiudp.so: lapi_udp.c,538)
 1522697263    12118336    1534815599   1507685061     9619348  __intel_ssse3_rep_memcpy (libirc.so)
  223197680     3086626     226284306    215787794     5879517  _lapi_shm_dispatcher (libpami.so: lapi_shm.c,2283)
```

```
  154744623     2075688     156820311     149803306     3979337  LapiImpl::Context::CheckContext (libpami.so:
CheckParam.cpp,21)
  151052863     2000330     153053193     146967548     3167039  LapiImpl::Context::Unlock<true, true, false>
(libpami.so: Context.h,204)
```

5 I/O Tracing and I/O Profiling

5.1 Open|SpeedShop I/O Tracing General Usage

The Open|SpeedShop (O|SS) *io* and *iot* I/O function tracing experiments wrap the most common I/O functions, record the time spent in each I/O function, record the call path along which I/O function was called, record the time spent along each call path to an I/O function, and record the number of times each function was called. In addition, the *iot* experiment also records information about each individual I/O function call. The values of the arguments and the return value from the I/O function are recorded.

5.2 I/O Base Tracing (io) experiment

The base I/O tracing experiment gathers data for the following I/O functions: close, creat, creat64, dup, dup2, lseek, lseek64, open, open64, pipe, pread, pread64, pwrite, pwrite64, read, readv, write, and writev. It is a trace type experiment that wraps the real I/O calls and records information before and after calling the real I/O functions. This, base, I/O experiment records the basic I/O information as stated in the introductory section, but does not record the arguments to each call. That is done in the extended (iot) experiment.

5.2.1 I/O Base Tracing (io) experiment performance data gathering

The base I/O tracing (io) experiment convenience script is "ossio". Use this convenience script in this manner to gather base I/O tracing performance data:

```
ossio "how you normally run your application" <list of I/O function(s)>
```

The following is an example of how to gather data for the IOP application on a Linux cluster platform using the ossio convenience script. It gathers performance data for all the I/O functions because there are no list I/O functions specified after the quoted application run command.

```
ossio  "srun -n 512 ./IOR"
```

5.2.2 I/O Base Tracing (io) experiment performance data viewing with CLI

To launch the CLI on any experiment, use "openss –cli –f <database name>".

5.2.3 I/O Base Tracing (io) experiment performance data viewing with GUI

To launch the GUI on any experiment, use "openss –f <database name>".

5.3 I/O Extended Tracing (iot) experiment

5.3.1 I/O Extended Tracing (iot) experiment performance data gathering

The extended I/O tracing (iot) experiment convenience script is "ossiot". Use this convenience script in this manner to gather extended I/O tracing performance data:

```
ossiot "how you normally run your application" <list of I/O function(s)>
```

The following is an example of how to gather data for the IOP application on a Linux cluster platform using the ossiot convenience script. It gathers performance data for all the I/O functions because there are no list I/O functions specified after the quoted application run command.

```
ossiot  "srun -n 512 ./IOR"
```

5.3.2 I/O Extended Tracing (iot) experiment performance data viewing with GUI

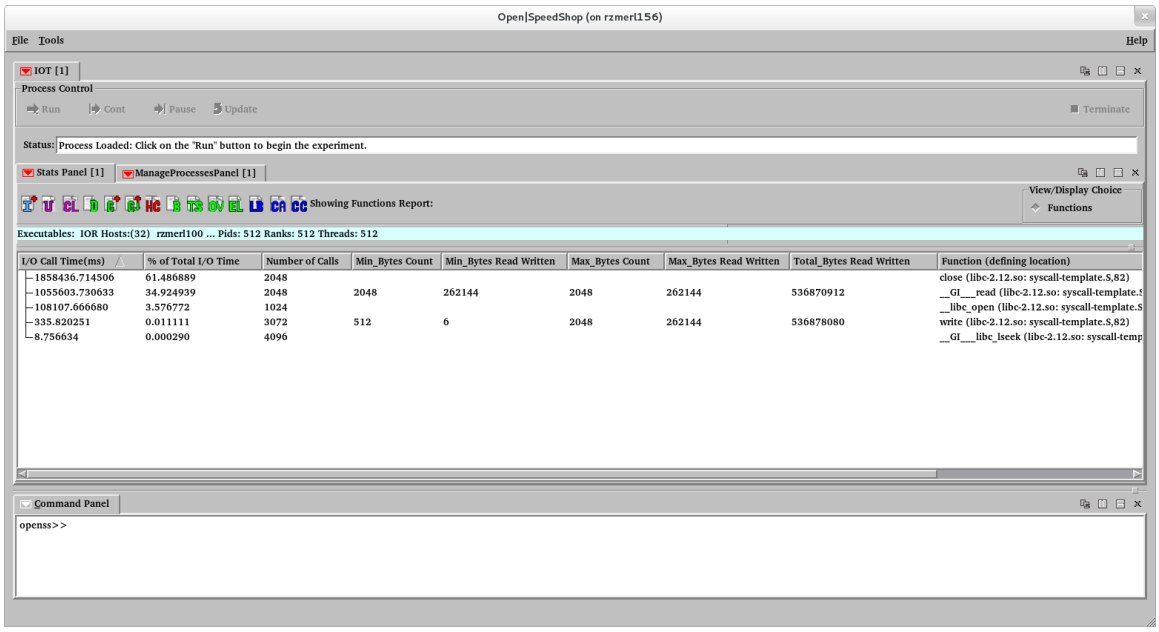
To launch the GUI on any experiment, use "openss –f <database name>".

This is the default GUI view for the iot experiment. This view gives a summary of the I/O functions that were called, how many times they were called and the amount of time spent in each function. The percentage of the total I/O time is also attributed to each I/O function. The time is aggregated (totaled) across all the threads, ranks, or processes that were part of the application. The table below describes what the columns of data represent.

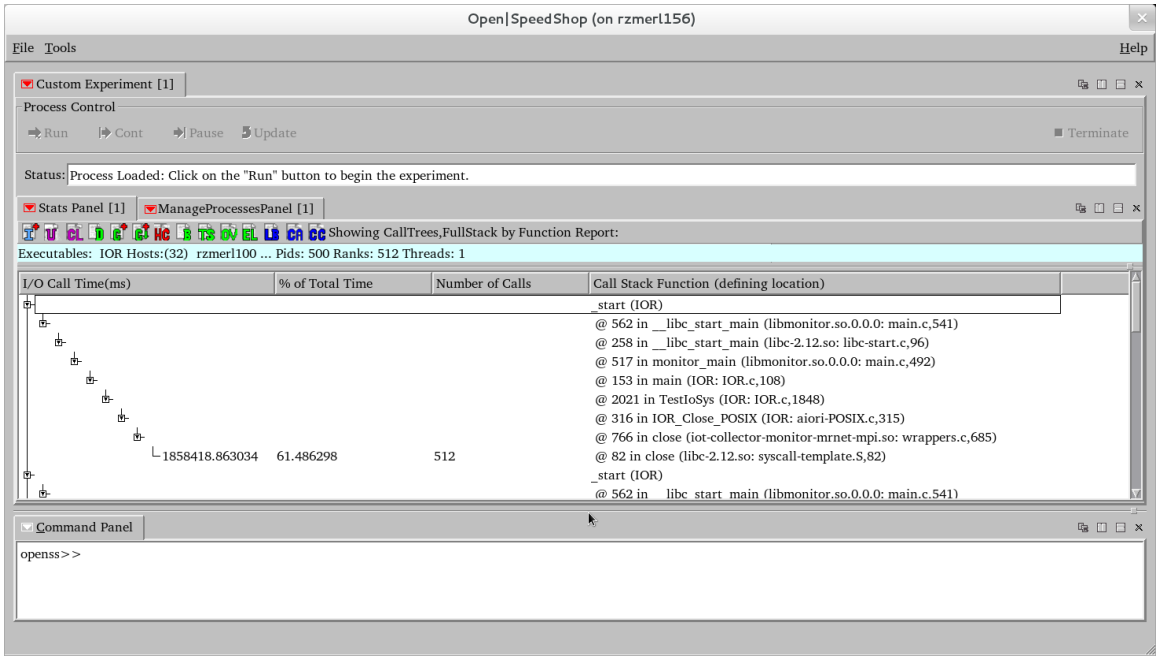
The functions that called the I/O functions are available by choosing one of the call path views.

Column Name	Column Definition
I/O Call Time	Aggregated total exclusive time spent in the I/O function corresponding to this row of data.
% of I/O Total Time	Percentage of exclusive time relative to the total time spent in the I/O function corresponding to this row of data.
Number of Calls	Total number of calls to the I/O function corresponding to this row of data.
Min Bytes Count	The number of times minimum bytes read or written by the corresponding I/O function occurred during this experiment.

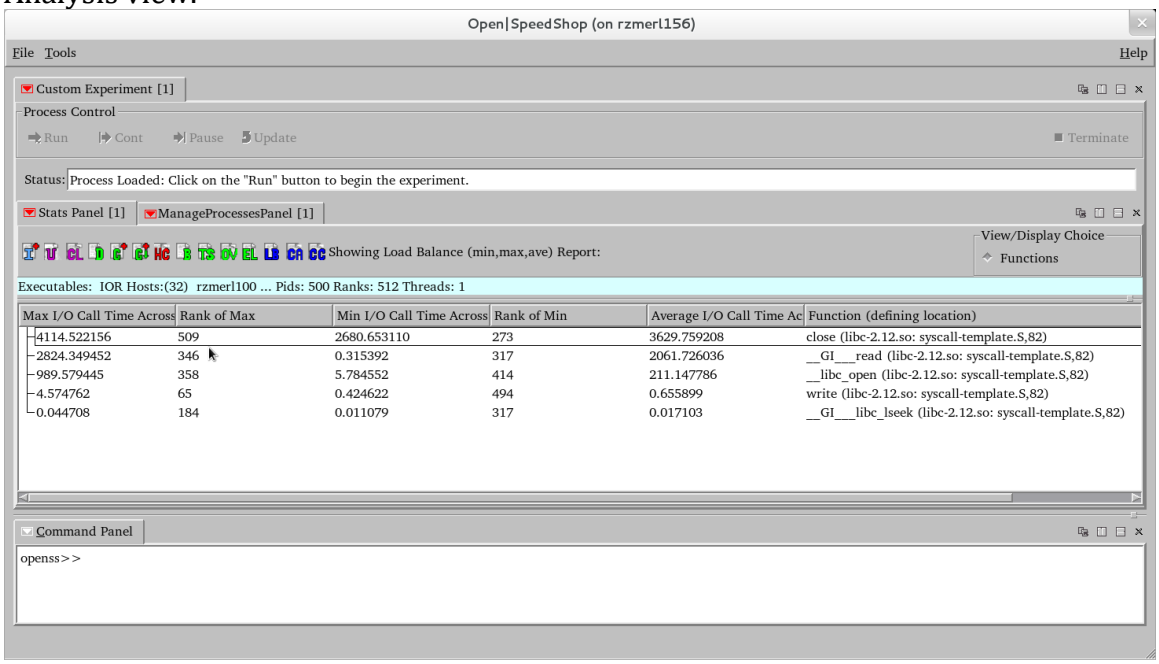
Column Name	Column Definition
Min Bytes Read or Written	The minimum number of bytes that were read or written by the corresponding I/O function.
Max Bytes Count	The number of times maximum bytes read or written by the corresponding I/O function occurred during this experiment.
Max Bytes Read or Written	The maximum number of bytes that were read or written by the corresponding I/O function.
Total Bytes Read or Written	The total number of bytes read or written by the corresponding function. This number only represents the totals for the number of bytes read or written based on the I/O function called.



Here the user has chosen the C+ view icon and the Stats Panel now shows all the call paths in the user's application. This view shows every possible call paths through the source to all the I/O functions that were called during the execution of this application. From this one could validate that this is expected behavior and if not find where the I/O in this application is not behaving as expected.

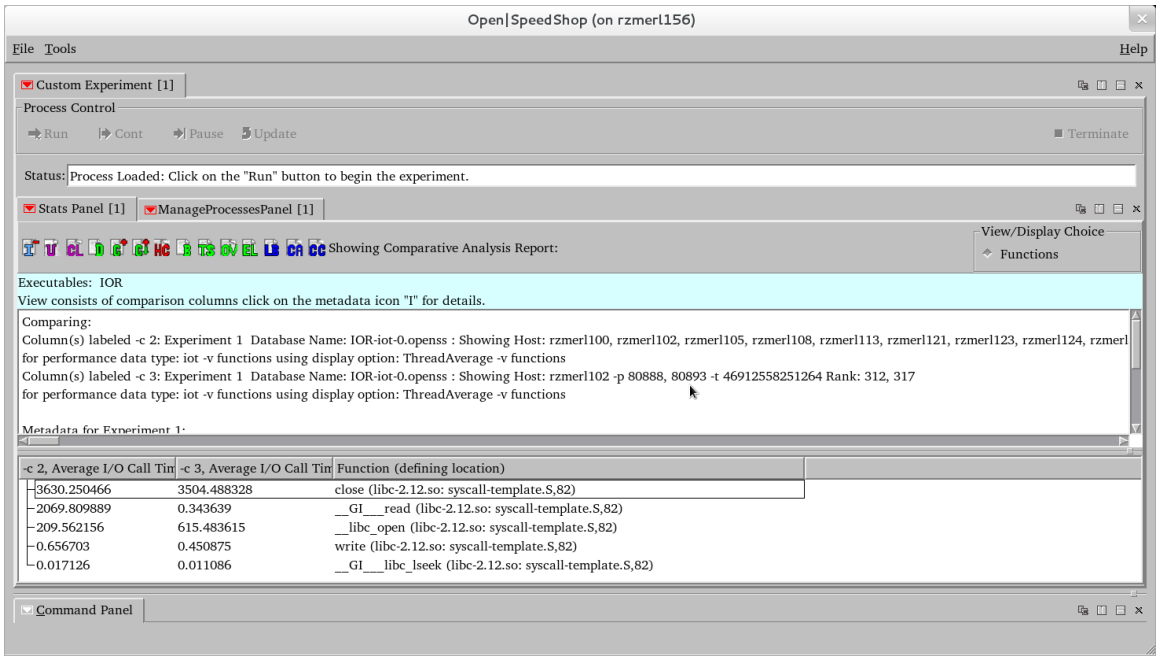


This view is the load balance view, which gives the min, max, average values for the I/O function call time across all the ranks in this application. In this view we are seeing some wide ranges between the min and max values for some of the I/O functions. It may be useful to see if we can identify the ranks by using the Cluster Analysis view.



This view, generated by choosing CA icon, the shows that there are two groups of ranks where the I/O is performing in similar manner. For group 2 (labeled –c 3 below), there are two ranks where the rest of the 512 ranks perform like group 1 (labeled –c 2 below). Investigation by examining ranks 312 or 317 by comparing it

to one of the ranks in the other group could shed some light on why group 2 is not similar to the rest. This may or may not be significant, but is here for illustration.



5.3.3 I/O Extended Tracing (iot) experiment performance data viewing with CLI

To launch the CLI on any experiment, use “openss –cli –f <database name>“.

The command line interface (CLI) can provide the same data options as the graphical user interface (GUI) views. Here are some examples of the performance data that can be viewed and the commands in order to generate the CLI views. The following table describes header and meaning of the default iot view CLI columns.

Column Name	Column Definition
I/O Call Time	Aggregated total exclusive time spent in the I/O function corresponding to this row of data.
% of I/O Total Time	Percentage of exclusive time relative to the total time spent in the I/O function corresponding to this row of data.
Number of Calls	Total number of calls to the I/O function corresponding to this row of data.
Min Bytes Count	The number of times minimum bytes read or written by the corresponding I/O function occurred during this experiment.
Min Bytes Read or Written	The minimum number of bytes that were read or written by the corresponding I/O function.
Max Bytes Count	The number of times maximum bytes read or written by the corresponding I/O function occurred during this experiment.
Max Bytes Read or Written	The maximum number of bytes that were read or written by the corresponding I/O function.

Column Name	Column Definition
Total Bytes Read or Written	The total number of bytes read or written by the corresponding function. This number only represents the totals for the number of bytes read or written based on the I/O function called.

```
>openss -cli -f IOR-iot.openss
openss>>[openss]: The restored experiment identifier is:  -x 1
openss>>expview

  I/O       % of          Number  Min_Bytes  Min_Bytes  Max_Bytes  Max_Bytes  Total_Bytes  Function (defining location)
 Call      Total          of      Count      Read       Count      Read       Read
           Time(ms)       I/O Calls          Written               Written    Written
Time
1858436.71  61.48     2048                                                    close (libc-2.12.so)
1055603.73  34.92     2048       2048    262144     2048       262144  536870912    __GI___read (libc-2.12.so)
 108107.66   3.57     1024                                                    __libc_open (libc-2.12.so)
    335.82   0.01     3072        512        6     2048       262144  536878080    write (libc-2.12.so)
      8.75   0.003    4096                                                    __GI___libc_lseek (libc-2.12.so)


# Show load balance based on exclusive time spent in the I/O Functions
openss>>expview -m loadbalance

  Max I/O      Rank    Min I/O      Rank    Average      I/O  Function (defining location)
 Call Time     of     Call Time    of      Call Time
   Across      Max      Across     Min       Across
 Ranks(ms)            Ranks(ms)           Ranks(ms)
4114.522156  509  2680.653110  273  3629.759208  close (libc-2.12.so: syscall-template.S,82)
2824.349452  346     0.315392  317  2061.726036  __GI___read (libc-2.12.so: syscall-template.S,82)
 989.579445  358     5.784552  414   211.147786  __libc_open (libc-2.12.so: syscall-template.S,82)
   4.574762   65     0.424622  494     0.655899  write (libc-2.12.so: syscall-template.S,82)
   0.044708  184     0.011079  317     0.017103  __GI___libc_lseek (libc-2.12.so: syscall-template.S,82)

# Show the call paths in the application run that allocated the largest number of bytes
# Using the min_bytes would show all the paths that allocated the minimum number of bytes.

openss>>expview -vfullstack -m max_bytes

Max_Bytes  Call Stack Function (defining location)
   Read
 Written
       _start (IOR)
       > @ 562 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
       >> @ 258 in __libc_start_main (libc-2.12.so: libc-start.c,96)
       >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
       >>>> @ 153 in main (IOR: IOR.c,108)
       >>>>> @ 2013 in TestIoSys (IOR: IOR.c,1848)
       >>>>>> @ 2608 in WriteOrRead (IOR: IOR.c,2562)
       >>>>>>> @ 244 in IOR_Xfer_POSIX (IOR: aiori-POSIX.c,224)
       >>>>>>>> @ 321 in write (iot-collector-monitor-mrnet-mpi.so: wrappers.c,239)
 262144  >>>>>>>>> @ 82 in write (libc-2.12.so: syscall-template.S,82)
       _start (IOR)
       > @ 562 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
       >> @ 258 in __libc_start_main (libc-2.12.so: libc-start.c,96)
       >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
       >>>> @ 153 in main (IOR: IOR.c,108)
       >>>>> @ 2173 in TestIoSys (IOR: IOR.c,1848)
       >>>>>> @ 2611 in WriteOrRead (IOR: IOR.c,2562)
       >>>>>>> @ 251 in IOR_Xfer_POSIX (IOR: aiori-POSIX.c,224)
       >>>>>>>> @ 223 in read (iot-collector-monitor-mrnet-mpi.so: wrappers.c,137)
 262144  >>>>>>>>> @ 82 in __GI___read (libc-2.12.so: syscall-template.S,82)
 ...
 ...

# Show the top time related call paths in the application run .
openss>>expview -v fullstack
```

```
   I/O Call      % of  Number  Call Stack Function (defining location)
   Time(ms)      Total     of
              Time   Calls
                     _start (IOR)
                     > @ 562 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
                     >> @ 258 in __libc_start_main (libc-2.12.so: libc-start.c,96)
                     >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
                     >>>> @ 153 in main (IOR: IOR.c,108)
                     >>>>> @ 2021 in TestIoSys (IOR: IOR.c,1848)
                     >>>>>> @ 316 in IOR_Close_POSIX (IOR: aiori-POSIX.c,315)
                     >>>>>>> @ 766 in close (iot-collector-monitor-mrnet-mpi.so: wrappers.c,685)
1858418.863034  61.486298    512  >>>>>>>> @ 82 in close (libc-2.12.so: syscall-template.S,82)
                     _start (IOR)
                     > @ 562 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
                     >> @ 258 in __libc_start_main (libc-2.12.so: libc-start.c,96)
                     >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
                     >>>> @ 153 in main (IOR: IOR.c,108)
                     >>>>> @ 2173 in TestIoSys (IOR: IOR.c,1848)
                     >>>>>> @ 2611 in WriteOrRead (IOR: IOR.c,2562)
                     >>>>>>> @ 251 in IOR_Xfer_POSIX (IOR: aiori-POSIX.c,224)
                     >>>>>>>> @ 223 in read (iot-collector-monitor-mrnet-mpi.so: wrappers.c,137)
1055603.730633  34.924939    2048  >>>>>>>>> @ 82 in __GI___read (libc-2.12.so: syscall-template.S,82)
                     _start (IOR)
                     > @ 562 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
                     >> @ 258 in __libc_start_main (libc-2.12.so: libc-start.c,96)
                     >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
                     >>>> @ 153 in main (IOR: IOR.c,108)
                     >>>>> @ 2004 in TestIoSys (IOR: IOR.c,1848)
                     >>>>>> @ 104 in IOR_Create_POSIX (IOR: aiori-POSIX.c,74)
                     >>>>>>> @ 670 in open64 (iot-collector-monitor-mrnet-mpi.so: wrappers.c,608)
 103350.518692   3.419380    512  >>>>>>>> @ 82 in __libc_open (libc-2.12.so: syscall-template.S,82)
                     _start (IOR)
                     > @ 562 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
                     >> @ 258 in __libc_start_main (libc-2.12.so: libc-start.c,96)
                     >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
                     >>>> @ 153 in main (IOR: IOR.c,108)
                     >>>>> @ 2161 in TestIoSys (IOR: IOR.c,1848)
                     >>>>>> @ 195 in IOR_Open_POSIX (IOR: aiori-POSIX.c,173)
                     >>>>>>> @ 670 in open64 (iot-collector-monitor-mrnet-mpi.so: wrappers.c,608)
  4757.147988   0.157392    512  >>>>>>>> @ 82 in __libc_open (libc-2.12.so: syscall-template.S,82)
                     _start (IOR)
                     > @ 562 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
                     >> @ 258 in __libc_start_main (libc-2.12.so: libc-start.c,96)
                     >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
                     >>>> @ 153 in main (IOR: IOR.c,108)
                     >>>>> @ 2013 in TestIoSys (IOR: IOR.c,1848)
                     >>>>>> @ 2608 in WriteOrRead (IOR: IOR.c,2562)
                     >>>>>>> @ 244 in IOR_Xfer_POSIX (IOR: aiori-POSIX.c,224)
                     >>>>>>>> @ 321 in write (iot-collector-monitor-mrnet-mpi.so: wrappers.c,239)
  316.176763   0.010461    2048  >>>>>>>>> @ 82 in write (libc-2.12.so: syscall-template.S,82)
```

5.3 I/O Lightweight Profiling (iop) General Usage

The Open|SpeedShop (O|SS) *iop* I/O function profiling experiment wraps the most common I/O functions, records the time spent in each I/O function, record the call path along which I/O function was called, record the time spent along each call path to an I/O function, and record the number of times each function was called.

5.3.1 I/O Profiling (iop) experiment performance data gathering

The I/O Profiling (iop) experiment convenience script is “ossiop”. Use this convenience script in this manner to gather lightweight I/O profiling performance data:

```
ossiop “how you normally run your application”
```

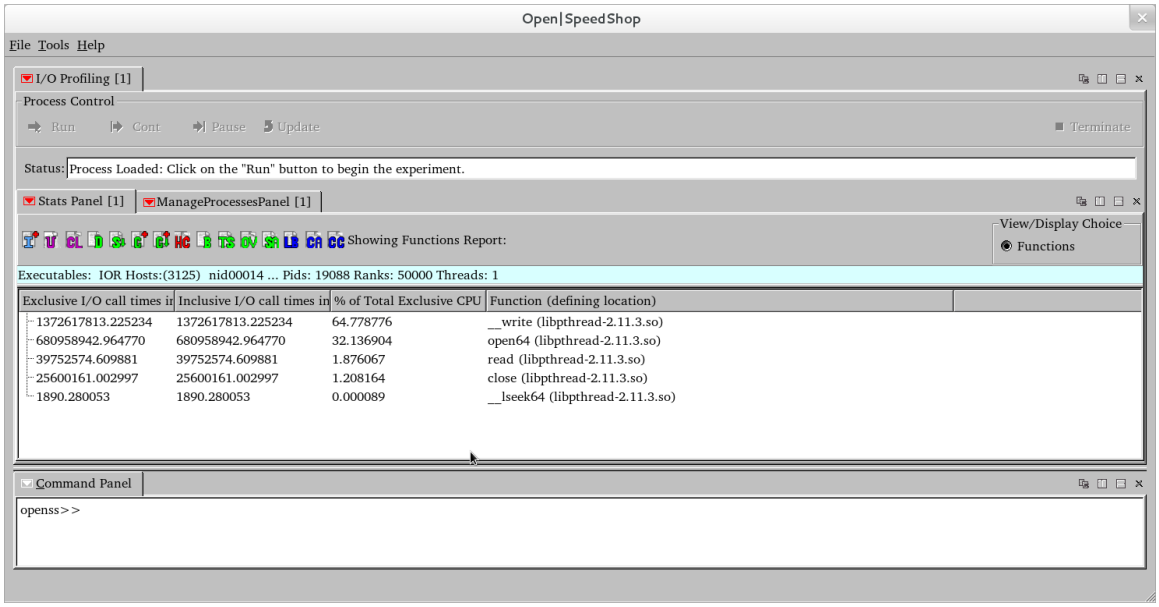
The following is an example of how to gather data for the IOP application on the Cray platform using the ossiop convenience script.

```
ossiop "aprun -n 64 ./IOR"
```

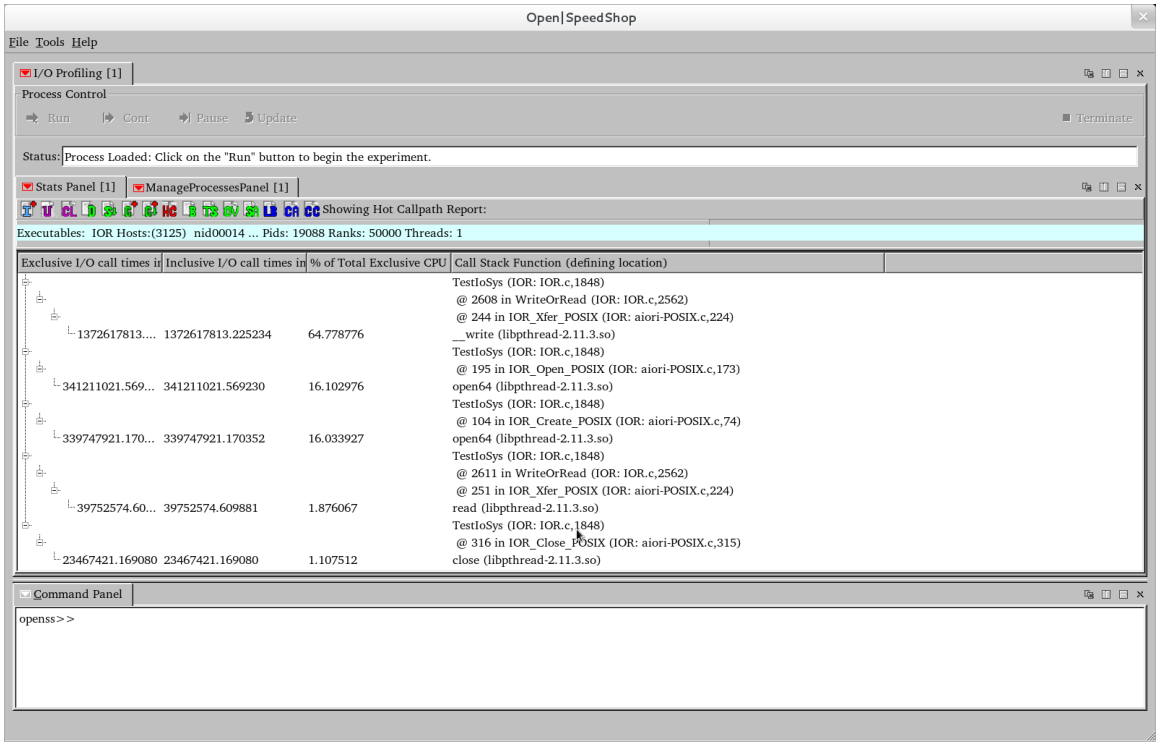
5.3.2 I/O Profiling (iop) experiment performance data viewing with GUI

To launch the GUI on any experiment, use “openss –f <database name>“.

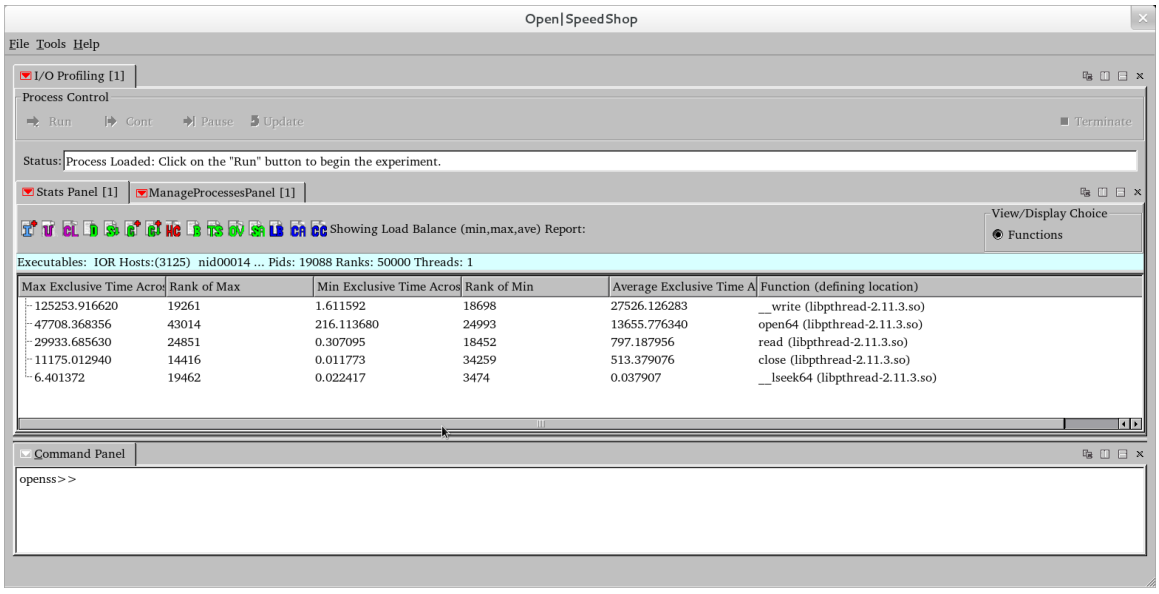
The first image, below, shows the default view for the iop experiment run on a 50000 rank IOR application job. The performance information in the default view is the time spent in I/O functions and the percentage of time spent in each I/O function.



In the image below, the hot call path view for the iop experiment run on a 50000 rank IOR application job is displayed. The performance information in the hot call path view is the top five call paths to each of the I/O functions that took the most time, time spent in I/O functions and the percentage of time spent in each I/O function.



This image shows the min, max, average time spent in each of the I/O functions showing the rank of the minimum value and the rank of the maximum value for each of the I/O functions. This view indicates if there is an imbalance relative to the I/O in the application being run. This may or may not be expected.



5.3.3 I/O Profiling (iop) experiment performance data viewing with CLI

To launch the CLI on any experiment, use “openss **–cli** –f <database name>“.

The command line interface (CLI) can provide the same data options as the graphical user interface (GUI) views. Here are some examples of the performance data that can be viewed and the commands in order to generate the CLI views.

```
> openss -cli -f IOR-iop-1.openss
openss>>[openss]: The restored experiment identifier is:  -x 1
openss>>expview

 Exclusive    Inclusive      % of  Function (defining location)
  I/O call    I/O call     Total
  times in    times in  Exclusive
  seconds.    seconds.  CPU Time
38297.33  38297.33    96.46     __write (libpthread-2.11.3.so)
  741.01      741.01     1.86     open64 (libpthread-2.11.3.so)
  598.43      598.43     1.50     read (libpthread-2.11.3.so)
   63.38       63.38     0.15     close (libpthread-2.11.3.so)
    2.264       2.26     0.01     __lseek64 (libpthread-2.11.3.so)

openss>>expview -v fullstack

 Exclusive    Inclusive      % of  Call Stack Function (defining location)
  I/O call    I/O call     Total
  times in    times in  Exclusive
  seconds.    seconds.  CPU Time
                        TestIoSys (IOR: IOR.c,1848)
                        > @ 2608 in WriteOrRead (IOR: IOR.c,2562)
                        >> @ 244 in IOR_Xfer_POSIX (IOR: aiori-POSIX.c,224)
38297.33  38297.33  96.46  >>>__write (libpthread-2.11.3.so)
                        TestIoSys (IOR: IOR.c,1848)
                        > @ 2611 in WriteOrRead (IOR: IOR.c,2562)
                        >> @ 251 in IOR_Xfer_POSIX (IOR: aiori-POSIX.c,224)
 598.43    598.43   1.51  >>>read (libpthread-2.11.3.so)
                        TestIoSys (IOR: IOR.c,1848)
                        > @ 104 in IOR_Create_POSIX (IOR: aiori-POSIX.c,74)
 472.14    472.14   1.19  >>open64 (libpthread-2.11.3.so)
                        TestIoSys (IOR: IOR.c,1848)
                        > @ 195 in IOR_Open_POSIX (IOR: aiori-POSIX.c,173)
 268.88    268.88   0.68 >>open64 (libpthread-2.11.3.so)
                        TestIoSys (IOR: IOR.c,1848)
                        > @ 316 in IOR_Close_POSIX (IOR: aiori-POSIX.c,315)
 61.587482    61.587482   0.155123  >>close (libpthread-2.11.3.so)
                        TestIoSys (IOR: IOR.c,1848)
                        > @ 316 in IOR_Close_POSIX (IOR: aiori-POSIX.c,315)
  1.796442     1.796442   0.004525  >>close (libpthread-2.11.3.so)
                        TestIoSys (IOR: IOR.c,1848)
                        > @ 2608 in WriteOrRead (IOR: IOR.c,2562)
                        >> @ 234 in IOR_Xfer_POSIX (IOR: aiori-POSIX.c,224)
  1.280113     1.280113   0.003224  >>>__lseek64 (libpthread-2.11.3.so)
                        TestIoSys (IOR: IOR.c,1848)
                        > @ 2611 in WriteOrRead (IOR: IOR.c,2562)
                        >> @ 234 in IOR_Xfer_POSIX (IOR: aiori-POSIX.c,224)
  0.981341     0.981341   0.002472  >>>__lseek64 (libpthread-2.11.3.so)
```

In the above command line interface output, the expview command with no options gives the overview or summary view for all the ranks and threads. One can view the performance information for individual ranks (using –r <rank number>) or

individual threads (using –t <thread number>) or individual processes (using –p <process id>). One can also give a range of ranks, threads, or processes using their respective option.

For the calltrees view, the display is showing where the I/O function was called from in the user's application source. In this example, most of I/O time was spent in the write I/O function along the path shown in the first individual call path. The call path with fullstack option forces the calltrees view to not collapse any similar sub-trees, which makes the view more explicit. Without the fullstack option the calltrees would be more consolidated.

6 Applying Experiments to Parallel Codes

The ideal scenario for the execution of parallel code using pthreads or OpenMP is efficient threading, where all threads are assigned work that can execute concurrently. Or for MPI code, the job is properly load balanced so all MPI ranks do the same about of work and no MPI rank is stuck waiting.

What are some things that can cause these ideal scenarios to fail? (taken from LLNL parallel processing tutorial) MPI jobs can become unbalanced if an equal amount of work was not assigned to each rank, possibly through the number of array operations not being equal for each rank or loop iterations not being evenly distributed. You can still have problems even if your work seems to be evenly distributed. For example, if you evenly distribute a sparsely populated array then some ranks may end up with very little or no work while others will have a full workload. With adaptive grid models some ranks need to redefine their mesh while other don't. With N-body simulations some work migrates to other ranks so those ranks will have more to do while the others have less.

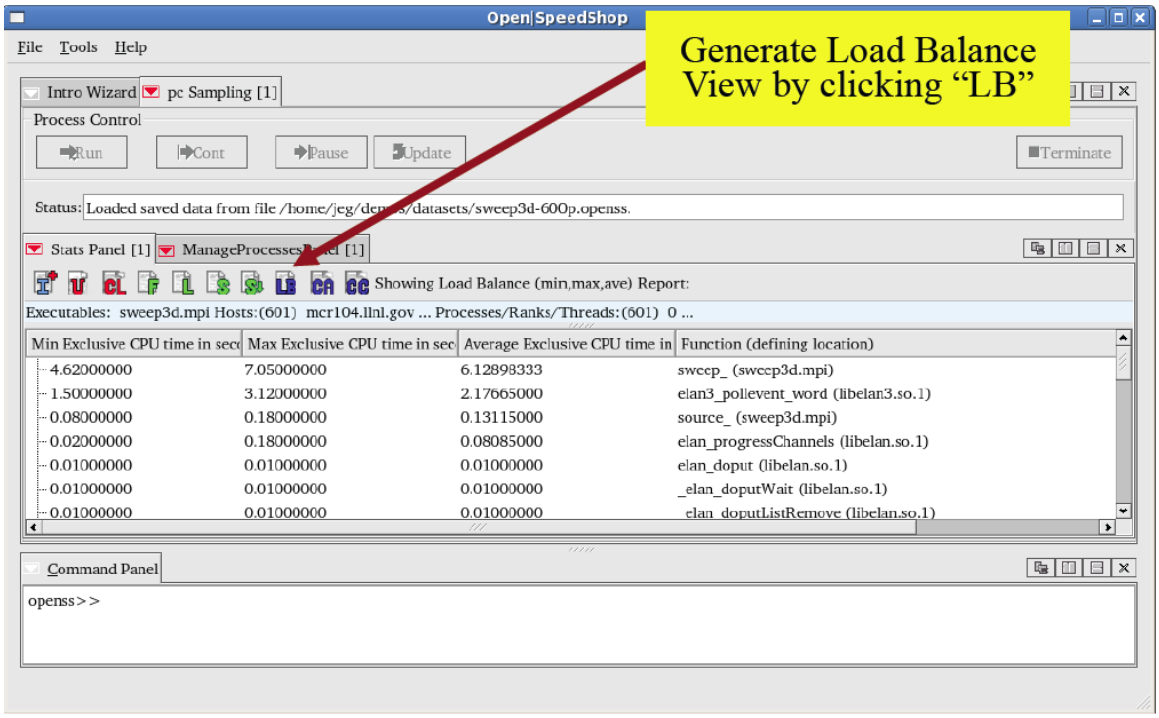
Performance analysis can help you with load balancing and an even distribution of work. Tools like O|SS are designed to work on parallel jobs. It supports threading and message passing and automatically tracks all ranks and thread during execution. It can also store the performance info per process, rank or thread for individual evaluation. All of the experiments for O|SS can be run on parallel jobs, collectors are applied to all ranks on all nodes. The results of an experiment can be displayed as an aggregation across all ranks or threads, which is the default view, or you can select individual or groups of ranks or threads to view. There are also experiments specifically designed for tracing MPI function calls.

O|SS has been tested with a variety of MPI versions including Open MPI, MVAPICH[2] and MPICH2 on Intel, Blue Gene, and Cray systems. O|SS is able to identify the MPI task (rank info) through the MPIR interface for the online version or through PMPI preload for the offline version. To run MPI code with O|SS just include the MPI launcher as part of the executable as normal, below are several examples:

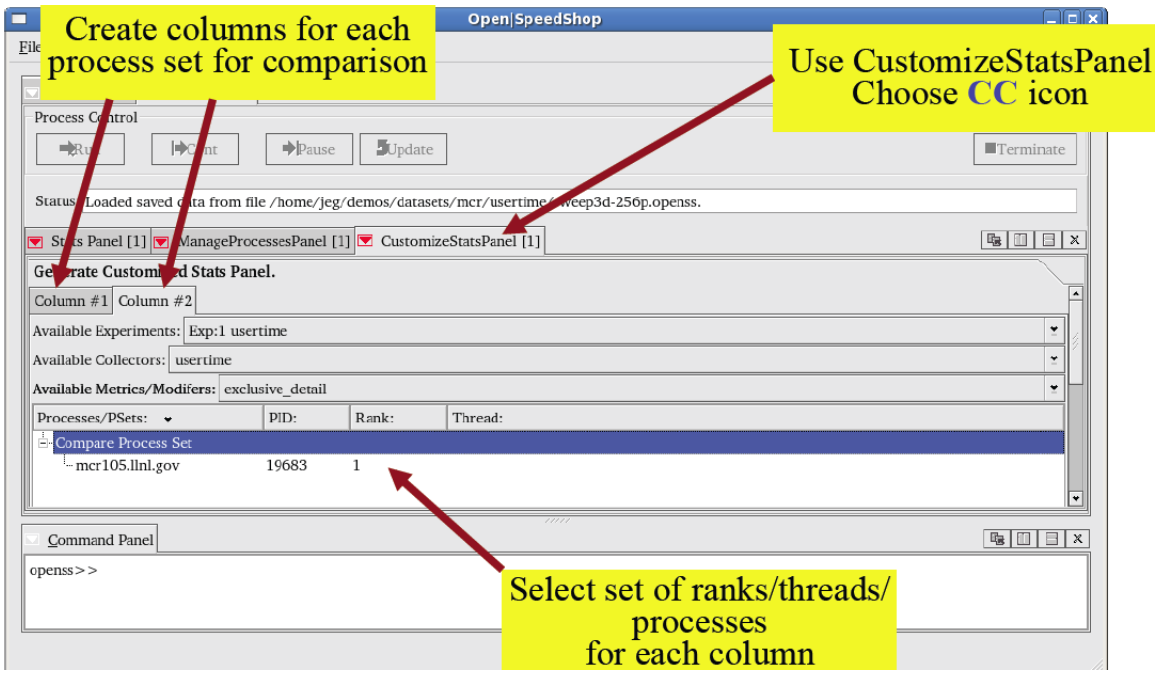
```
> ossmpi "mpirun –np  128 sweep3d.mpi"

> osspcsamp "mpirun –np 32 sweep3d.mpi"

> ossio "srun –N 4 –n 16 sweep3d.mpi"

> openss –offline –f "mpirun –np 128 sweep3d.mpi" hwctime

> openss –online –f "srun –N 8 –n 128 sweep3d.mpi" usertime
```

The default view for parallel applications is to aggregate the information collected across all ranks. You can manually include or exclude individual ranks, processes or

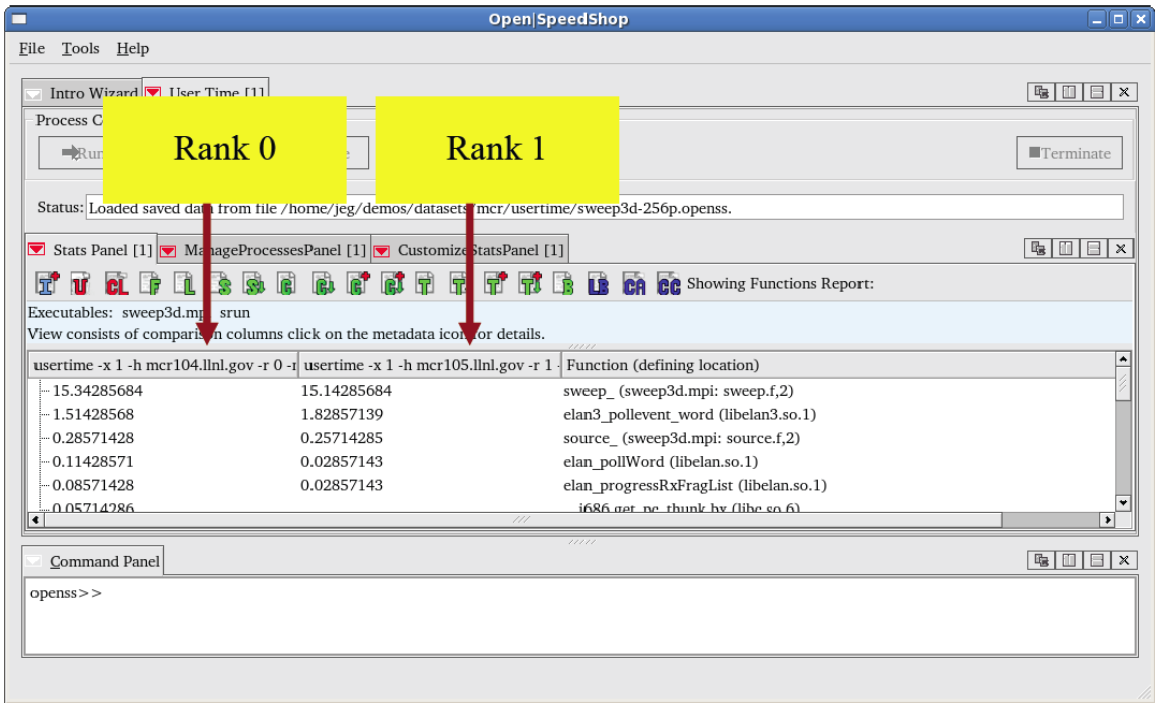
threads to view their specific results. You can also compare ranks by using the Customize Stats Panel View and creating a compare column for the process groups or individual ranks. Cluster analysis is also available, it can be used to find outliers, ranks that are performing very differently than the others. From the Stats Panel toolbar or context menu you can automatically create groups of similar performing ranks or threads. Through the Stat Panel O|SS also provides common analysis functions designed for quick analysis of MPI applications. There are load balance views that calculate min, max and average values across ranks, processes or threads. The image below shows the O|SS buttons for Load Balance and next to that Cluster Analysis.



Below we see the creation of a comparison between to ranks in O|SS.



Now we see those to ranks compared side by side in the statistics panel.



7 MPI Tracing Experiments (mpi, mpit, mpip)

In this section we will go through an MPI tracing experiment with O|SS. The experiment will record all MPI call invocations. There are three MPI experiments and associated convenience scripts, ossmpi, which will record call times ossmpit,

which will record call times and arguments, and mpip which is a lightweight version of of mpi, where individual MPI calls are recorded but not saved in the database. Equal events will be aggregated to save space in the database as well as to reduce the overhead.

Again we will run experiment on the smg2000 application. The syntax for the experiment is:

```
> ossmpi[t][p] "srun –N 4 –n 32 smg2000 –n 50 50 50" [default | <list MPI functions> | mpi_category]
```

The default behavior is to trace all MPI functions, but a comma separated list of MPI functions can be giving if you only want to trace specific functions, e.g. MPI_Send, MPI_Recv…, etc. You can also select an mpi_category to trace: "all", "asynchronous_p2p", "collective_com", "datatypes", "environment", "graphs_contexts_comms", "persistent_com", "process_topologies", and "synchronous_p2p".

The default views are designed to relate the information, included in the report, back to the individual calls to their corresponding MPI functions. This is the same information that would be reported if the user were to do an: "expview -m min, max, average". The view is a representation of the minimum, maximum and average time values per individual calls to their corresponding MPI functions.

The average time reported is the total amount of time for all the calls to a function divided by the total number of calls. Thus, it is the average time that each individual call spends in the function. As such, it is comparable to the Max (maximum) and Min (minimum) of a call to the function that is in the same "min, max, average" report.

Alternatively, if a user does an "expview -m ThreadMin, ThreadMax, ThreadAve", then the report information is related for the Max, Min and Average is related back to the individual ranks.

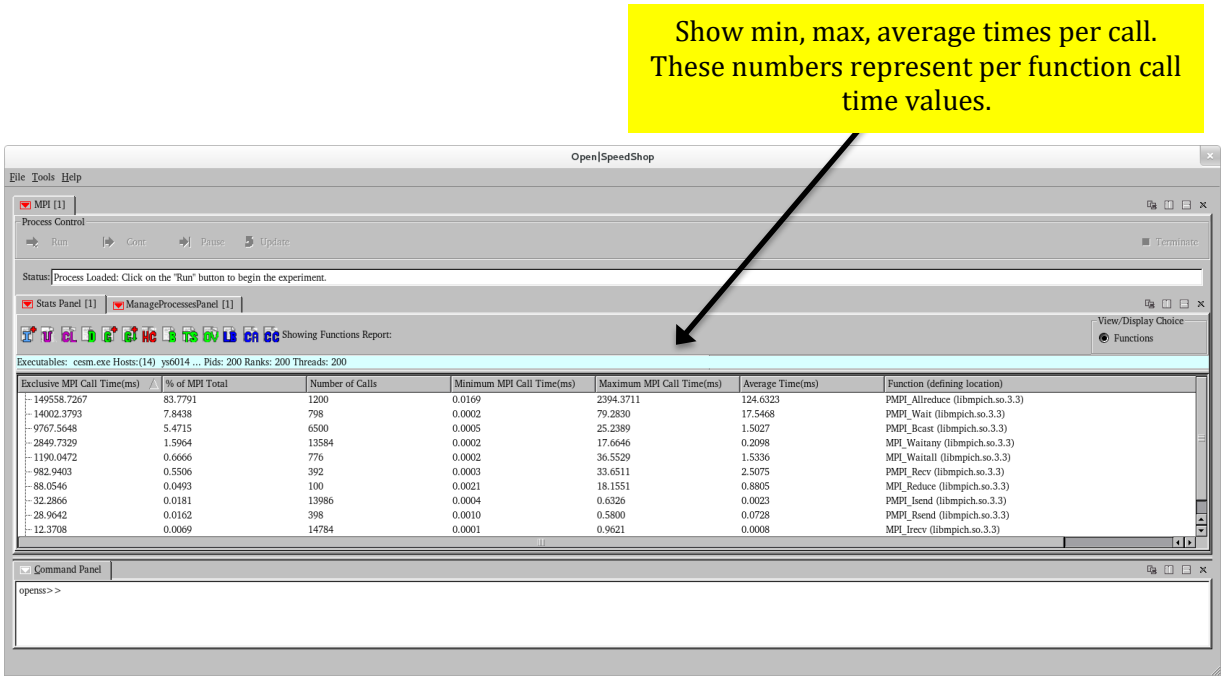
Another way of saying it is: The average is the total amount of time for all the calls to a function divided by the total number of ranks. Thus it is the average time that each rank spends in the function. As such, it is comparable to the Max and Min of a rank that is in the same report.

If the number of ranks is the same as the number of calls, the two different calculations should produce the same result. This would be true if all the calls were in a single thread or there were one in each rank, as it is for MPI_Init.

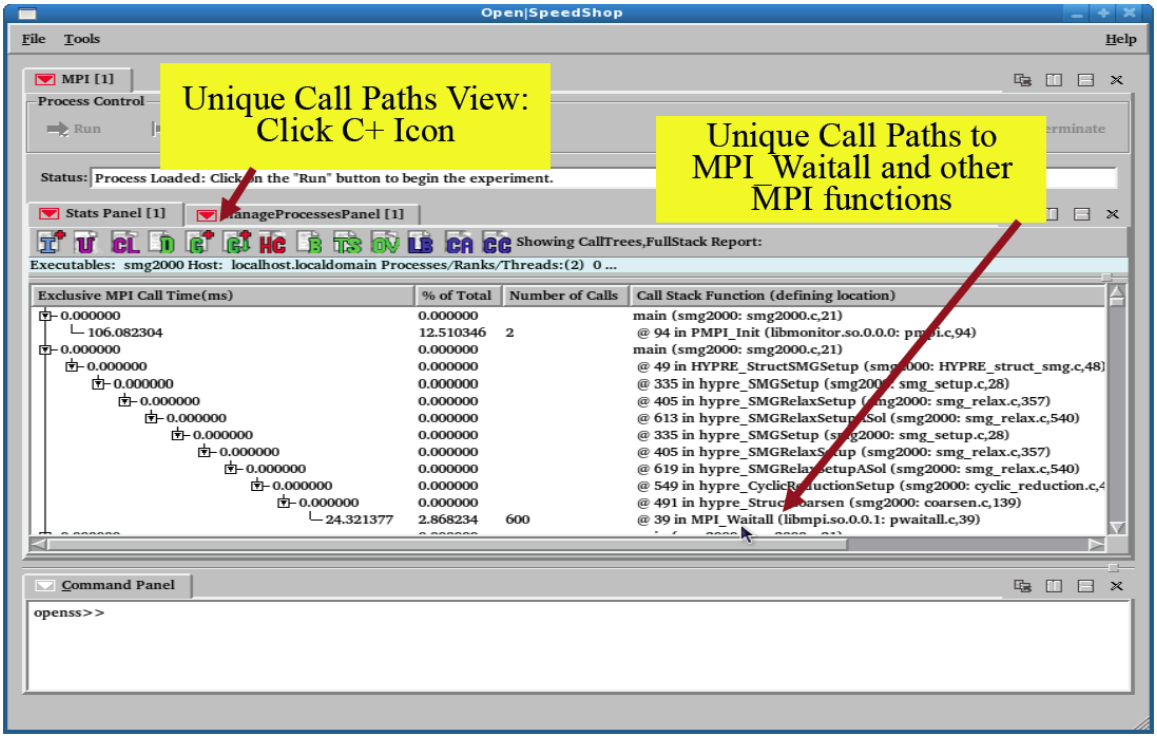
The "expview -m min, max, average" view can expose load imbalance by showing when the minimum and maximum time for asynchronous MPI functions have large differences. This situation indicates that some of the MPI asynchronous functions ran quickly (low minimum times) but some had to wait a long time to get started

(large maximum times). Many times the function calls that ran quickly were the last to arrive and actually are from ranks that are not running as well as the others, causing load imbalance and delays to the overall job execution speed. These ranks show better performance numbers in terms of the MPI function time, but that is only because they were the last to arrive at the internal barrier point and did not have to wait as long as the other MPI functions that arrived sooner, but had to wait for the other ranks to finally arrive.

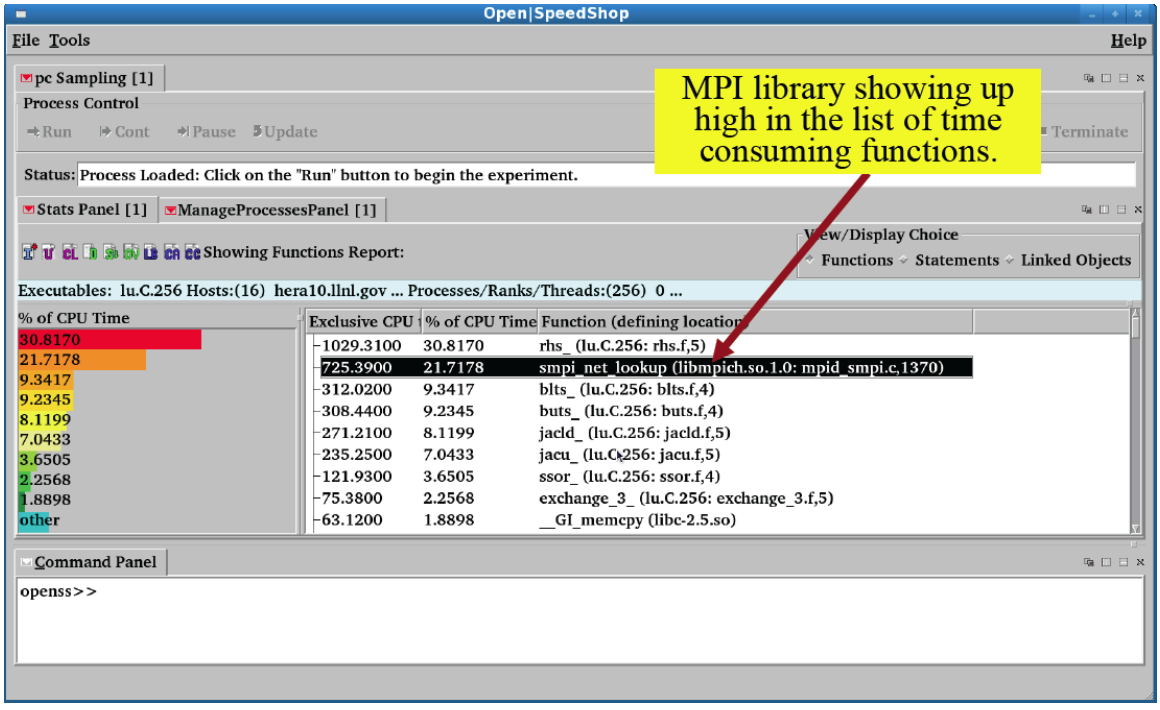
The image below shows the results of the MPI experiment in the default view.



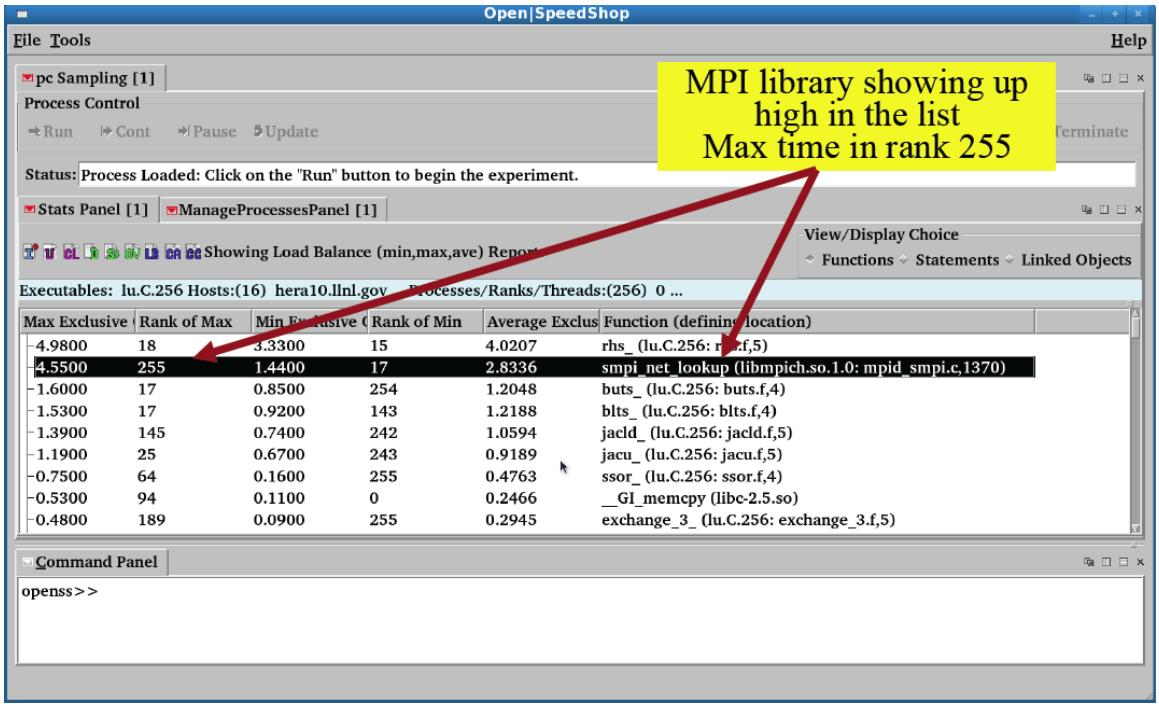
Next we see the MPI function call path view, shown below.



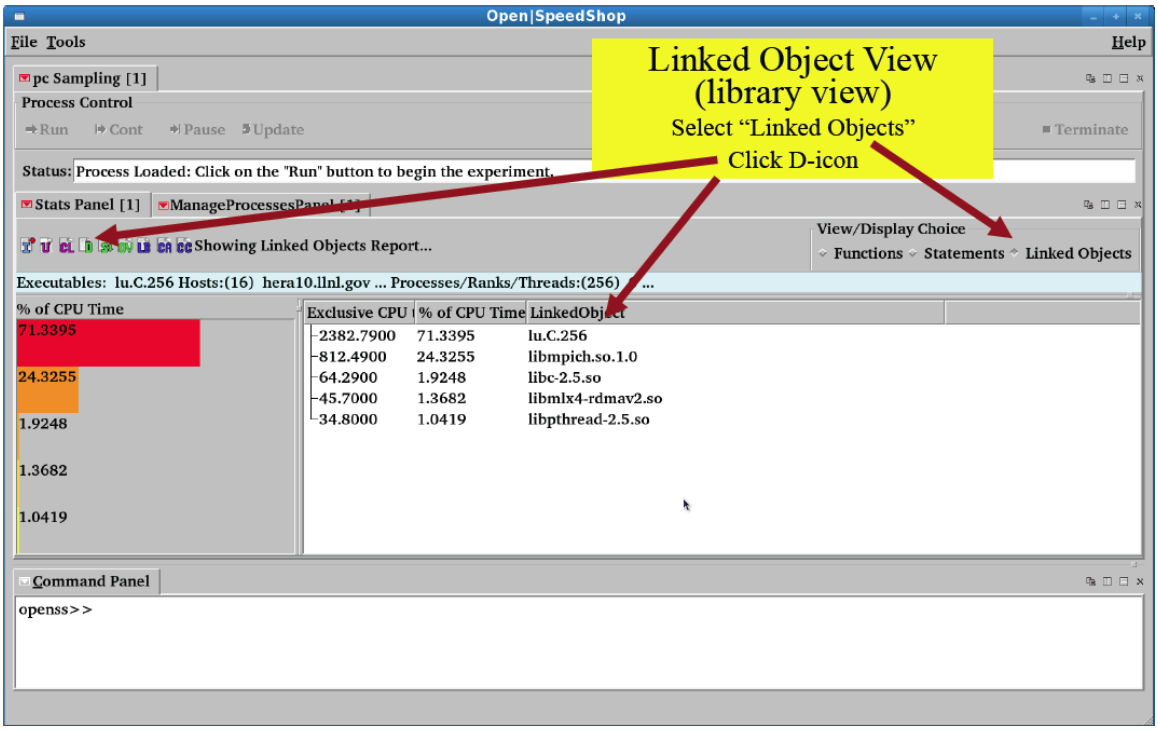
Here is the default pcsamp view based on functions.



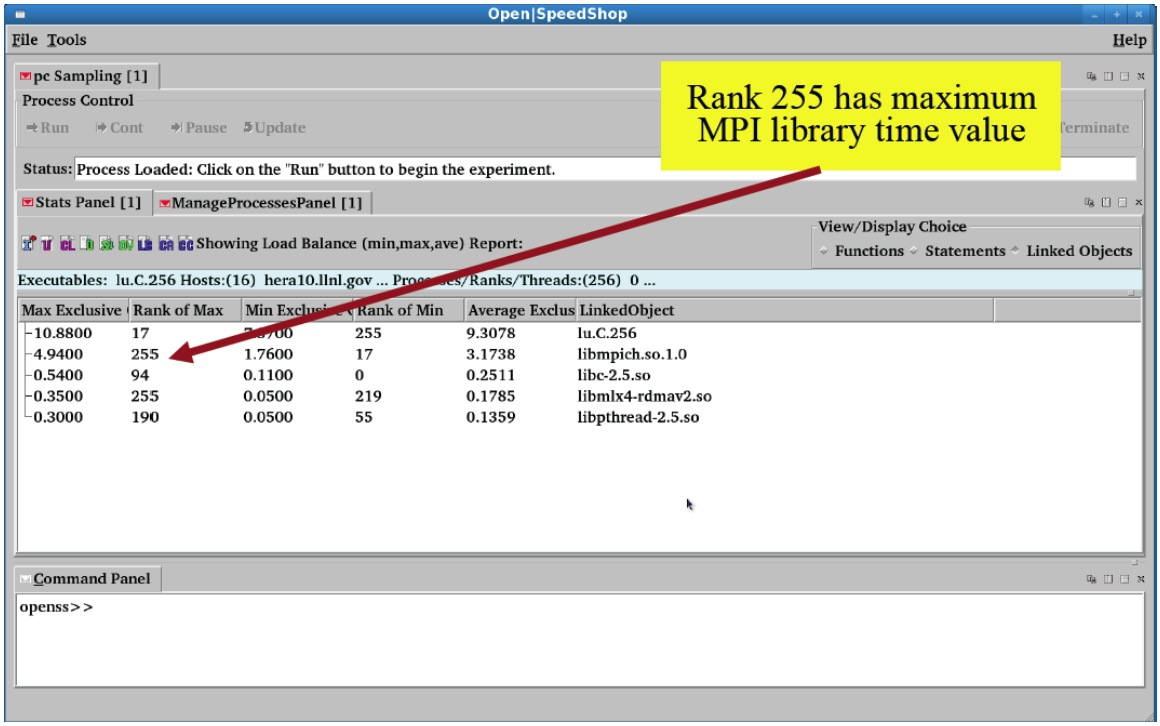
Here is the load balance view based on functions.



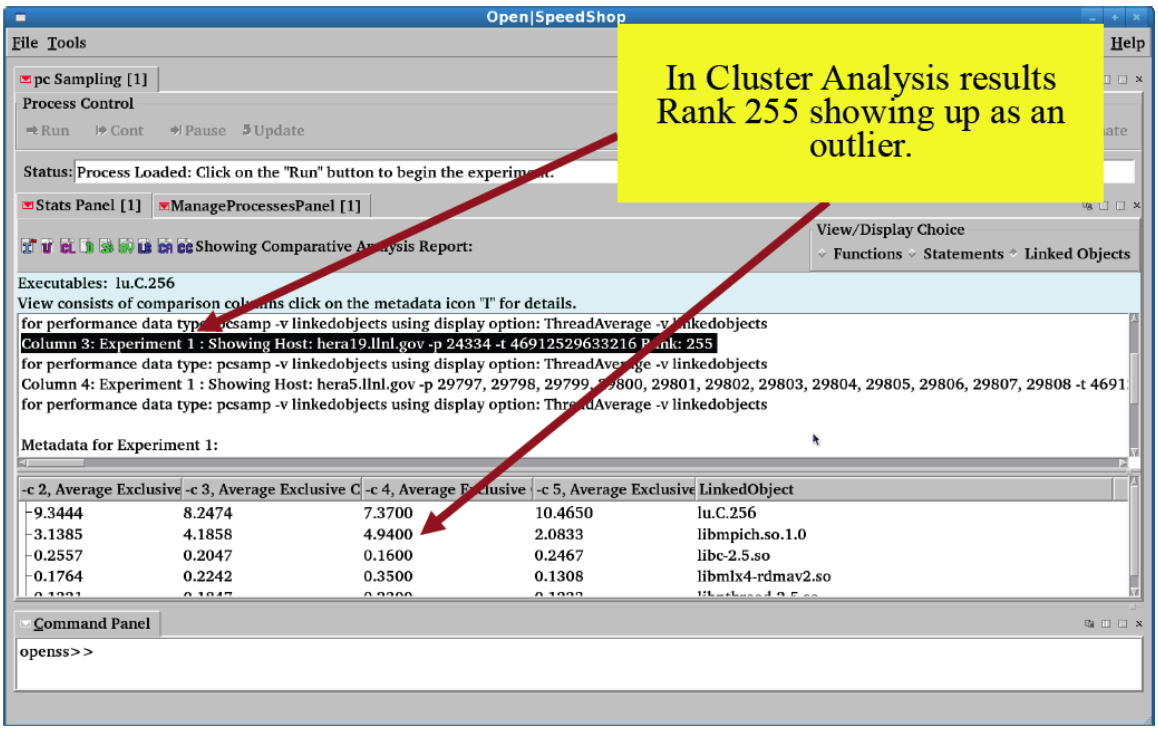
Here is the default view based on Linked Objects (libraries).



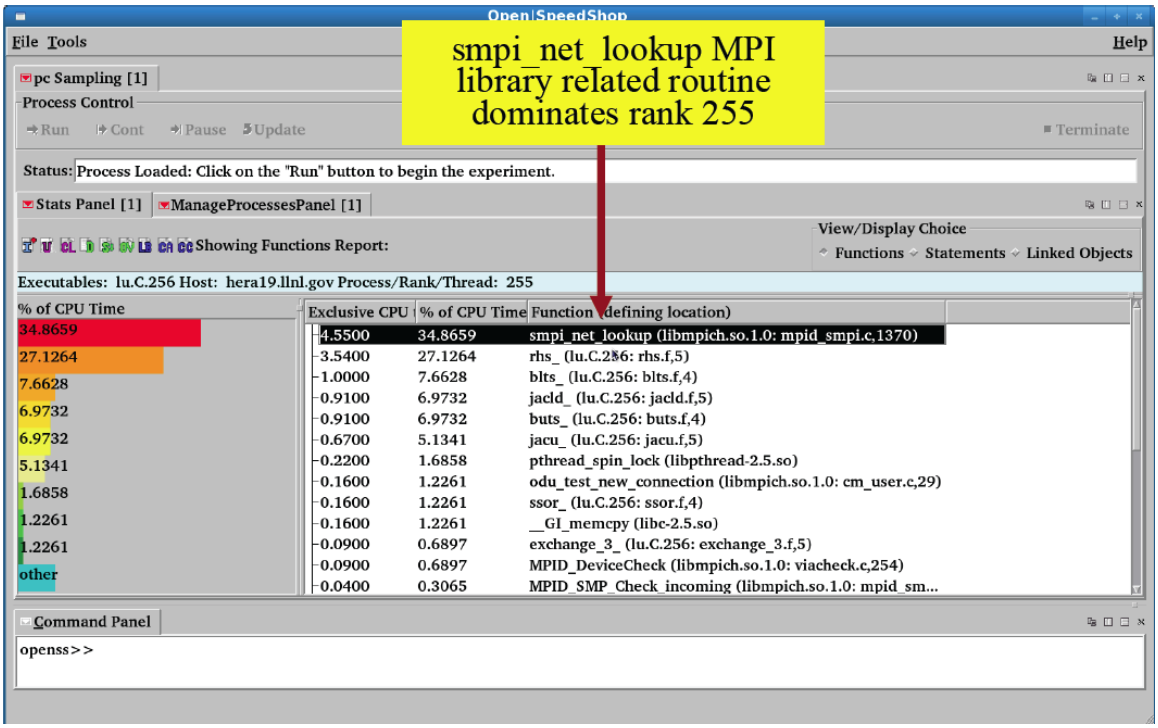
Next we see the load balance view base on Linked Objects (libraries).



Here we see the cluster analysis view based on Linked Objects.



Here is the pcsamp view of Rank 255 performance data only.



Below we examine Rank 255 further but this time using the load balance view in the Command Line Interface for O|SS.

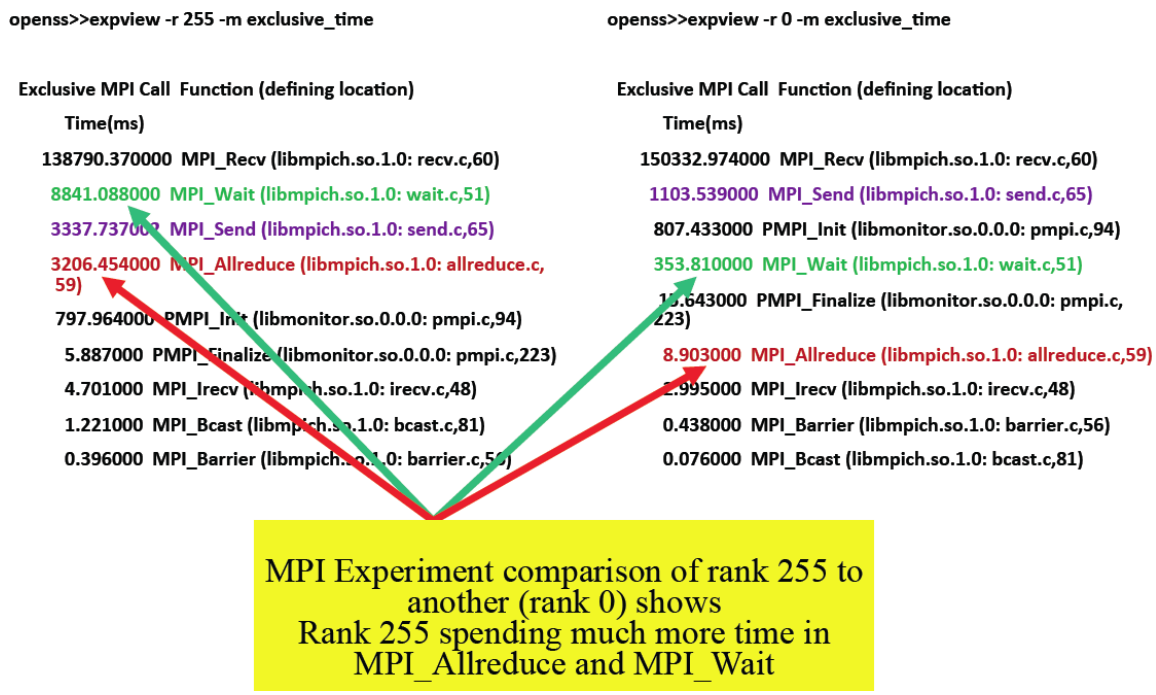
```
openss>>expview -m loadbalance
```

Max MPI Call Time (defining location) Across Ranks(ms)	Rank of Max	Min MPI Call Time Across Ranks(ms)	Rank of Min	Average MPI Call Function Time Across Ranks(ms)
150332.97	0	120351.97	36	131361.13 MPI_Recv (libmpich.so.1.0: recv.c,60)
17636.11	36	1103.53	0	5443.08 MPI_Send (libmpich.so.1.0: send.c,65)
16470.53	19	353.81	0	5255.33 MPI_Wait (libmpich.so.1.0: wait.c,51)
3206.45	255	3.00	17	2000.27 MPI_Allreduce (libmpich.so.1.0: allreduce.c,59)
915.17	54	754.39	83	792.07 PMPI_Init (libmonitor.so.0.0.0: pmpi.c,94)
16.00	48	5.63	249	7.29 PMPI_Finalize (libmonitor.so.0.0.0: pmpi.c,223)
9.28	230	2.99	0	7.55 MPI_Irecv (libmpich.so.1.0: irecv.c,48)
1.22	247	0.07	0	1.10 MPI_Bcast (libmpich.so.1.0: bcast.c,81)
0.51	53	0.35	239	0.41 MPI_Barrier (libmpich.so.1.0: barrier.c,56)

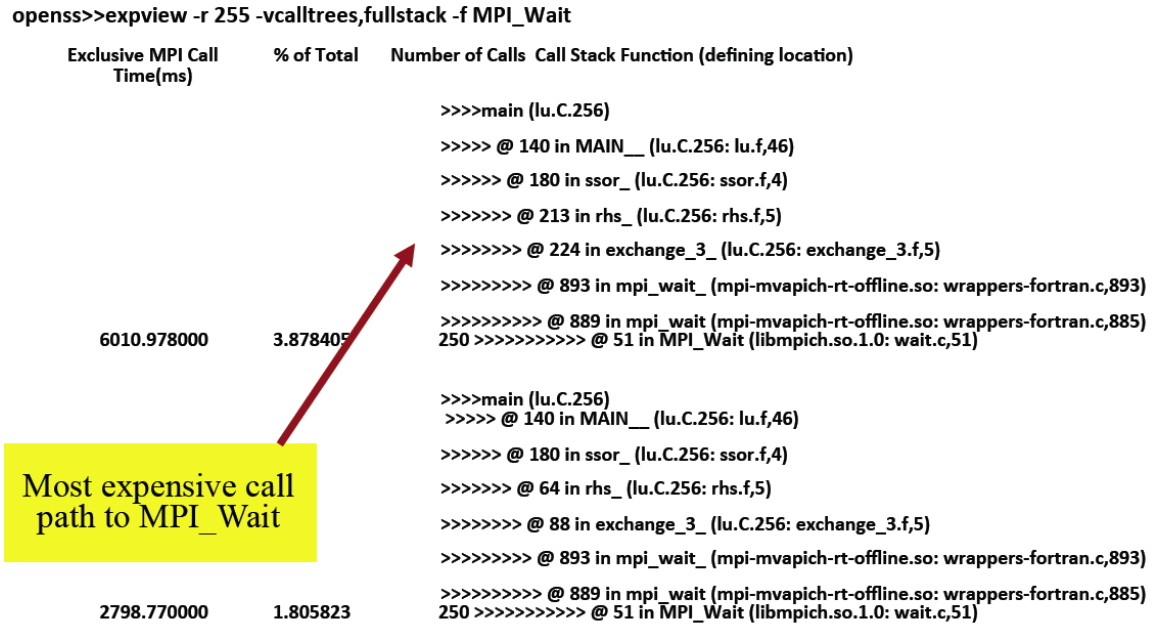
openss>>

MPI Experiment shows Rank 255 spending significant time in MPI_Allreduce

Here we look at the difference between Rank 255 and Rank 0.



Next we see the hot call paths for MPI_Wait on Rank 255.

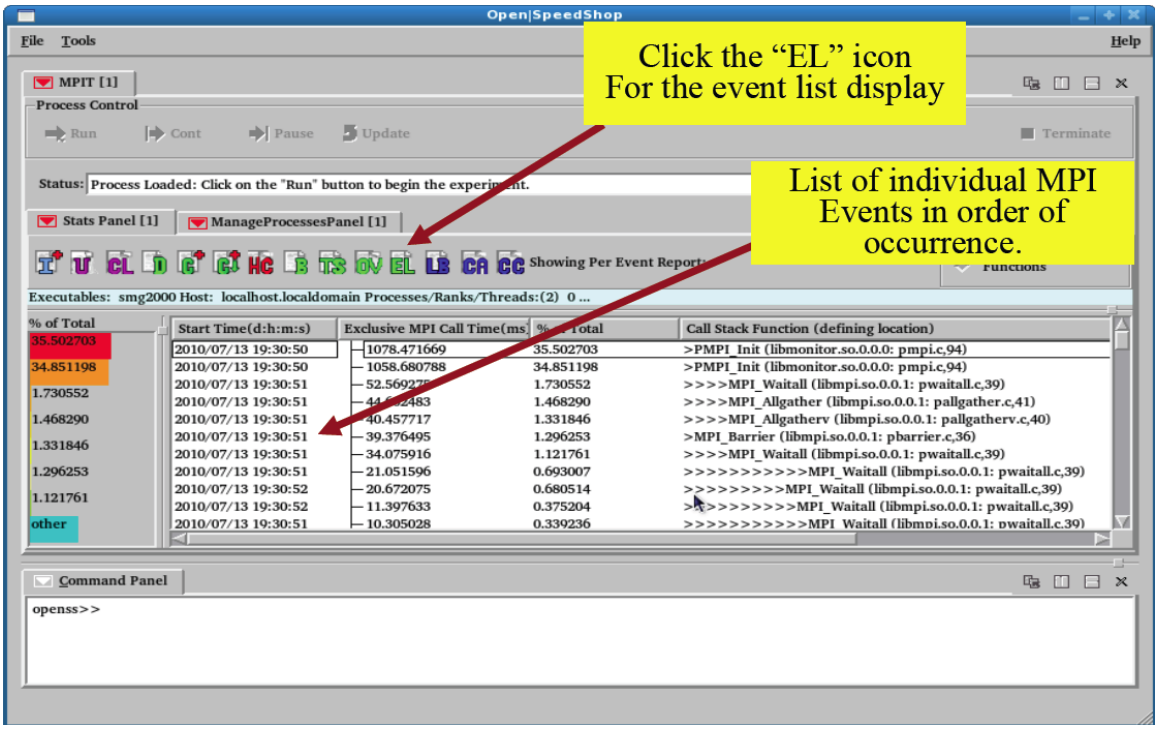


In this experiment we did program counter sampling to get an overview of the application. We noticed that smp_net_lookup showed up in function load balance view, which caused us to take a look at the linked object view. The load balance on the linked object showed some imbalance, so we looked at the cluster analysis view and found that rank 255 was an outlier.

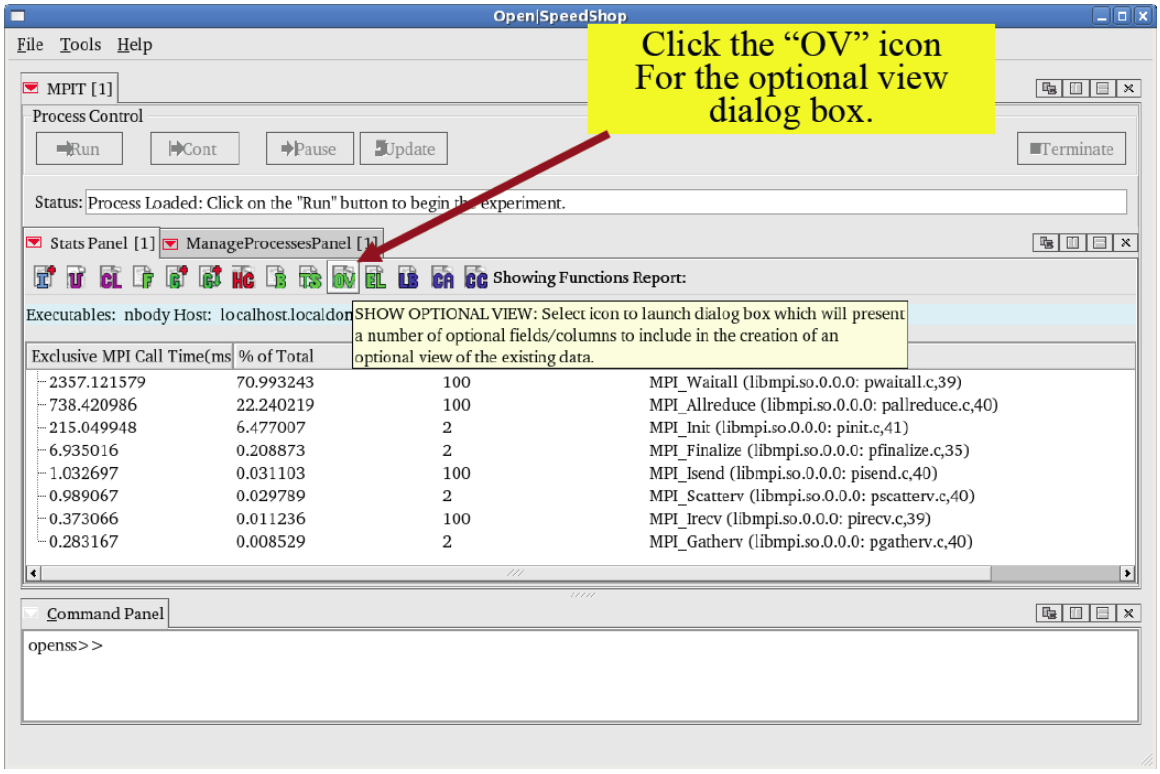
We then took a closer look at rank 255 and saw that the pcsamp output shows most of the time was spent in smp_net_lookup. We used the MPI experiment to determine if we can get more clues and saw that a load balance view on the MPI experiment shows rank 255's MPI_Allreduce time is the highest of the 256 ranks. We then looked at rank 255 and a representative rank from the rest of the ranks and noted the differences in MPI_Wait, MPI_Send and MPI_Allreduce. We looked at the call paths to MPI_Wait to determine why the wait was occurring.

The mpit experiment has a performance information entry for each MPI function call. In addition to the time spent in each MPI function, information like source and destination rank, bytes sent or received are also available. You can selectively view the information you desire.

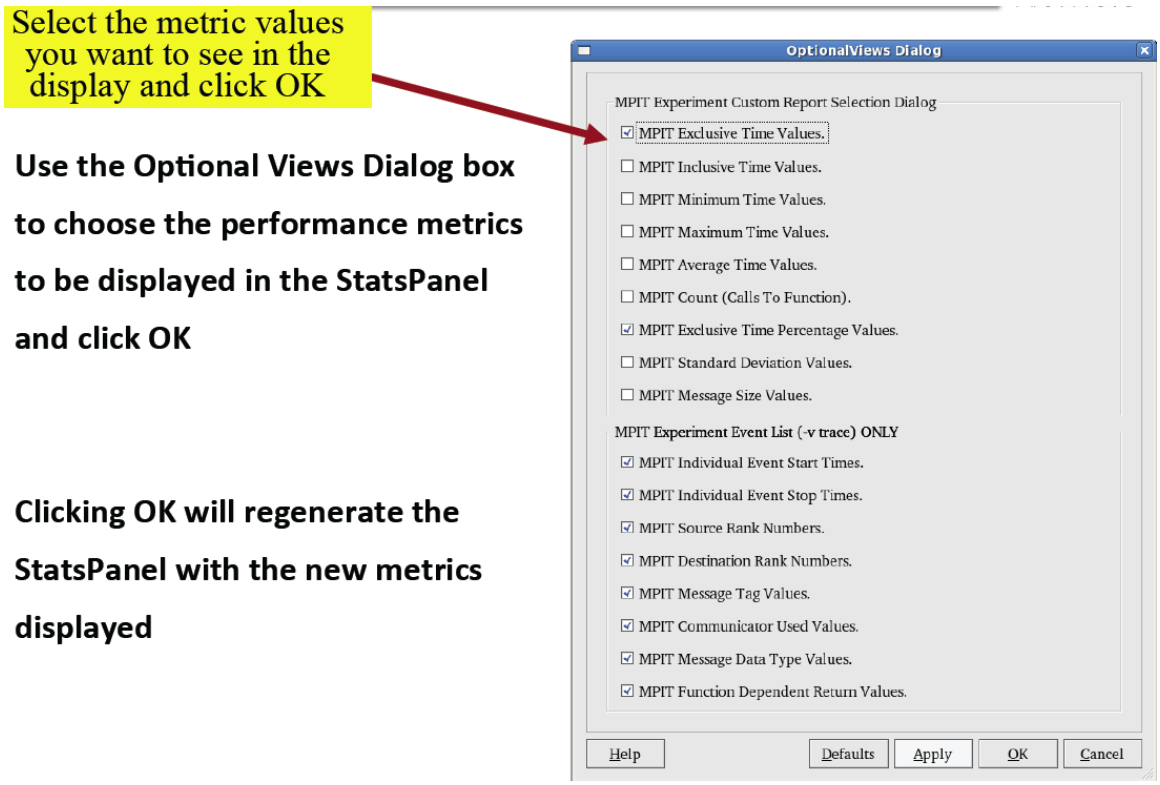
Below we see the default event view for an MPI application.



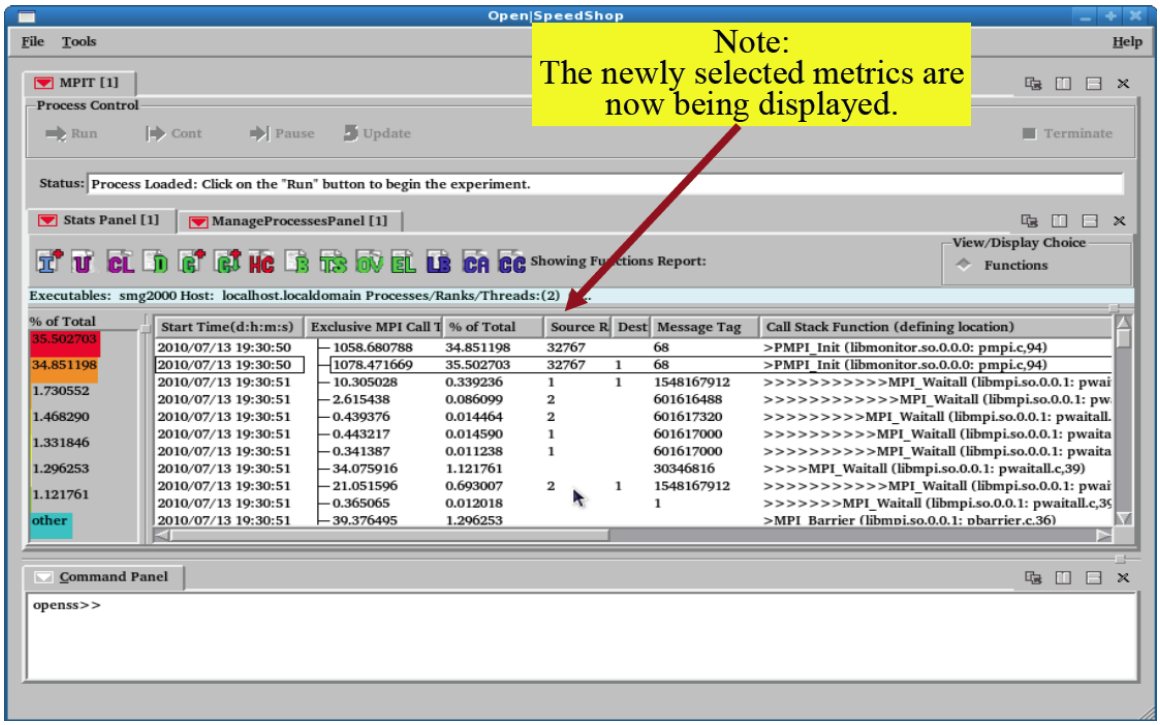
We can create our own event view with the OV button.



You can use the views dialog box to choose what metric to display.



After choosing the event to view it will then be displayed.



7.1 MPI Tracing Experiment (mpi)

7.1.1 MPI Tracing Experiment (mpi) performance data gathering

Much of this information is described above in the main MPI Tracing Experiments section, but for completeness, this is the convenience script description for running the MPI specific tracing experiments.

> ossmpi “srun –N 4 –n 32 smg2000 –n 50 50 50” [default | <list MPI functions> | mpi_category]

If the mpi_category or a list of categories is given to the ossmpi command, then only those the MPI function corresponding to that category will be traced. The MPI categories are defined according to the table below.

MPI Category	Argument
All MPI Functions	all
Collective Communicators	collective_com
Persistent Communicators	persistent_com
Synchronous Point to Point	synchronous_p2p
Asynchronous Point to Point	asynchronous_p2p
Process Topologies	process_topologies
Groups Contexts Communicators	graphs_contexts_comms
Environment	environment
Datatypes	datatypes
MPI File I/O	fileio

7.1.2 MPI Tracing Experiment (mpi) performance data viewing with GUI

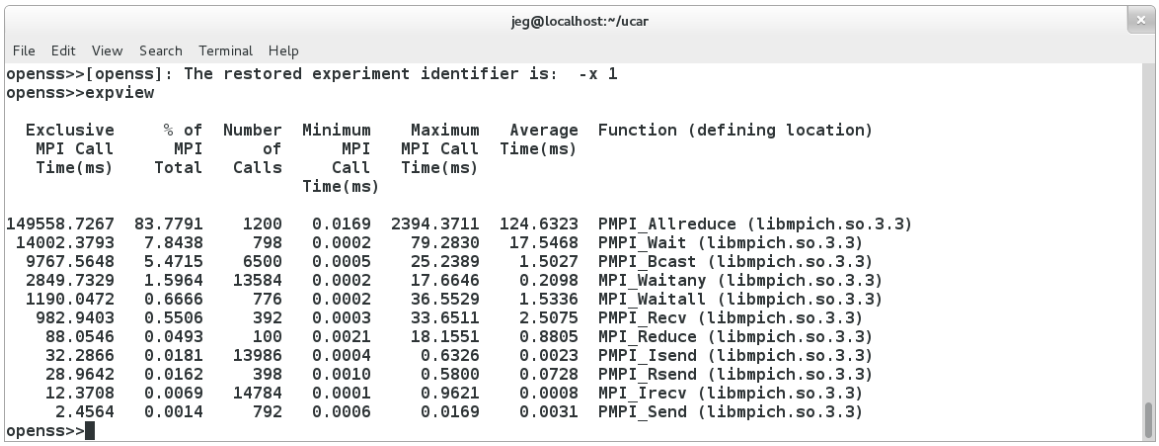
To launch the GUI on any experiment, use “openss –f <database name> “.

7.1.3 MPI Tracing Experiment (mpi) performance data viewing with CLI

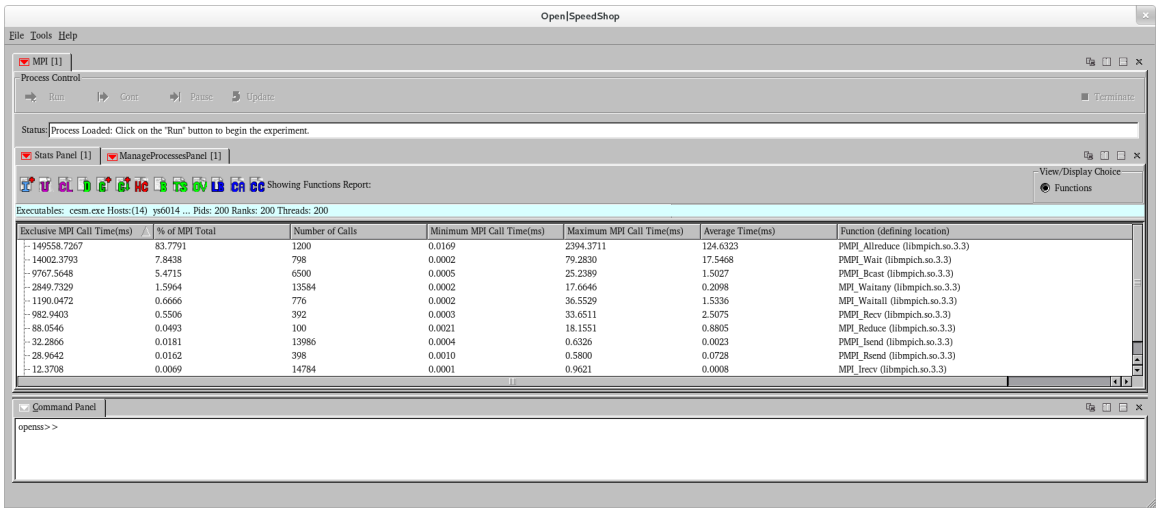
To launch the CLI on any experiment, use “openss –cli –f <database name>“.
The following table describes the header and column data definitions for the default MPI experiment views.

Column Name	Column Definition
Exclusive MPI Call Time	Aggregated total exclusive time spent in the MPI function corresponding to this row of data.
% of MPI Time	Percentage of exclusive MPI time spent in the MPI function corresponding to this row of data relative to the total MPI time for all the MPI functions.
Number of Calls	Total number of calls to the MPI function corresponding to this row of data.
Min MPI Call Time	The minimum time that a MPI call took across all calls spent in the corresponding MPI function.
Max MPI Call Time	The maximum time that a MPI call took across all calls spent in the corresponding MPI function.
Average MPI Call Time Across Ranks	The average time for the default view is the total amount of time for all the calls to a function divided by the total number of calls. Thus, it is the average time that each MPI function call spends in the function.

This is an example of the CLI default view for the MPI (mpi, mpit) experiments.



This is an example of the GUI default view for the MPI (mpi, mpit) experiments.



The default views are designed to relate the information, included in the report, back to the individual calls to their corresponding MPI functions. This is the same information that would be reported if the user were to do: "expview -m min, max, average". The view is a representation of the minimum, maximum and average time values per individual calls to their corresponding MPI functions.

The average time reported is the total amount of time for all the calls to a function divided by the total number of calls. Thus, it is the average time that each individual call spends in the function. As such, it is comparable to the Max (maximum) and Min (minimum) of a call to the function that is in the same "min, max, average" report.

Alternatively, if a user does an "expview -m ThreadMin, ThreadMax, ThreadAve", then the report information is related for the Max, Min and Average is related back to the individual ranks.

Another way of saying it is: The average is the total amount of time for all the calls to a function divided by the total number of ranks. Thus it is the average time that each rank spends in the function. As such, it is comparable to the Max and Min of a rank that is in the same report.

If the number of ranks is the same as the number of calls, the two different calculations should produce the same result. This would be true if all the calls were in a single thread or there were one in each rank, as it is for MPI_Init.

The "expview -m min, max, average" view can expose load imbalance by showing when the minimum and maximum time for asynchronous MPI functions have large differences. This situation indicates that some of the MPI asynchronous functions ran quickly (low minimum times) but some had to wait a long time to get started (large maximum times). Many times the function calls that ran quickly were the last to arrive and actually are from ranks that are not running as well as the others,

causing load imbalance and delays to the overall job execution speed. These ranks show better performance numbers in terms of the MPI function time, but that is only because they were the last to arrive at the internal barrier point and did not have to wait as long as the other MPI functions that arrived sooner, but had to wait for the other ranks to finally arrive.

7.2 MPI Tracing Experiments (mpit)

7.2.1 MPI Tracing Experiments (mpit) performance data gathering

Much of this information is described above in the main MPI Tracing Experiments section, but for completeness, this is the convenience script description for running the MPI specific tracing experiments.

```
> ossmpit "srun –N 4 –n 32 smg2000 –n 50 50 50" [default | <list MPI functions> | mpi_category]
```

If the mpi_category or a list of categories is given to the ossmpit command, then only those the MPI function corresponding to that category will be traced. The MPI categories are defined according to the table below.

MPI Category	Argument
All MPI Functions	all
Collective Communicators	collective_com
Persistent Communicators	persistent_com
Synchronous Point to Point	synchronous_p2p
Asynchronous Point to Point	asynchronous_p2p
Process Topologies	process_topologies
Groups Contexts Communicators	graphs_contexts_comms
Environment	environment
Datatypes	datatypes
MPI File I/O	fileio

7.2.2 MPI Tracing Experiments (mpit) performance data viewing with GUI

To launch the GUI on any experiment, use "openss –f <database name>".

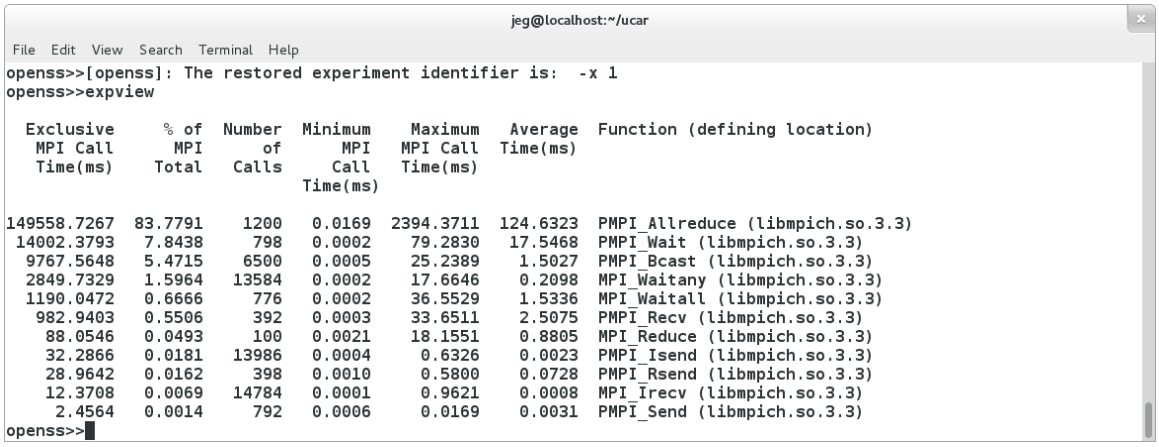
7.2.3 MPI Tracing Experiments (mpit) performance data viewing with CLI

To launch the CLI on any experiment, use "openss –cli –f <database name>".
The following table describes the header and column data definitions for the default MPI experiment views.

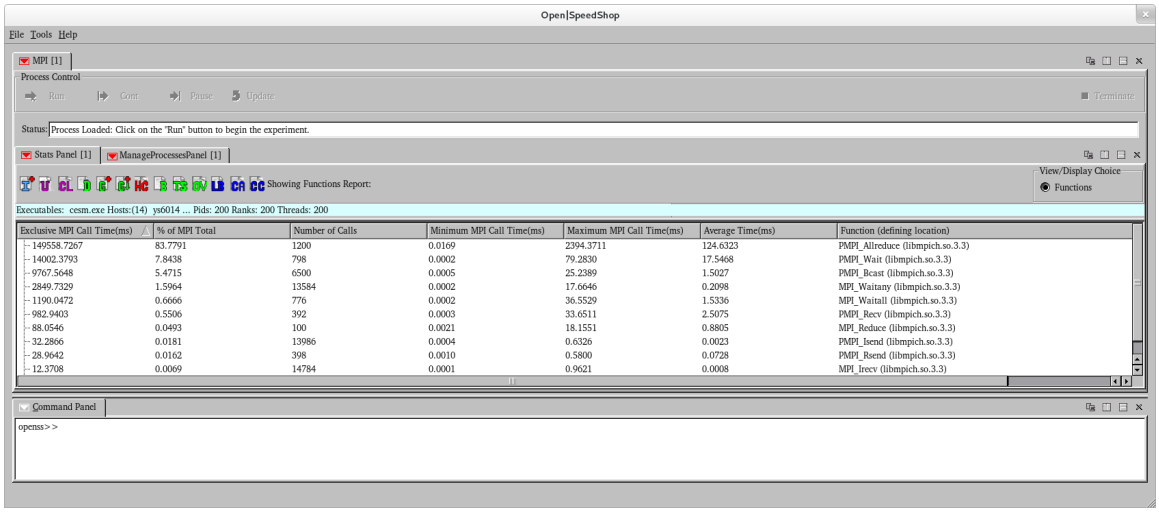
Column Name	Column Definition
Exclusive MPI Call Time	Aggregated total exclusive time spent in the MPI function corresponding to this row of data.

Column Name	Column Definition
% of MPI Time	Percentage of exclusive MPI time spent in the MPI function corresponding to this row of data relative to the total MPI time for all the MPI functions.
Number of Calls	Total number of calls to the MPI function corresponding to this row of data.
Min MPI Call Time	The minimum time that a MPI call took across all calls spent in the corresponding MPI function.
Max MPI Call Time	The maximum time that a MPI call took across all calls spent in the corresponding MPI function.
Average MPI Call Time Across Ranks	The average time for the default view is the total amount of time for all the calls to a function divided by the total number of calls. Thus, it is the average time that each MPI function call spends in the function.

This is an example of the CLI default view for the MPI (mpi, mpit) experiments.



This is an example of the GUI default view for the MPI (mpi, mpit) experiments.



The default views are designed to relate the information, included in the report, back to the individual calls to their corresponding MPI functions. This is the same information that would be reported if the user were to do: "expview -m min, max, average". The view is a representation of the minimum, maximum and average time values per individual calls to their corresponding MPI functions.

The average time reported is the total amount of time for all the calls to a function divided by the total number of calls. Thus, it is the average time that each individual call spends in the function. As such, it is comparable to the Max (maximum) and Min (minimum) of a call to the function that is in the same "min, max, average" report.

Alternatively, if a user does an "expview -m ThreadMin, ThreadMax, ThreadAve", then the report information is related for the Max, Min and Average is related back to the individual ranks.

Another way of saying it is: The average is the total amount of time for all the calls to a function divided by the total number of ranks. Thus it is the average time that each rank spends in the function. As such, it is comparable to the Max and Min of a rank that is in the same report.

If the number of ranks is the same as the number of calls, the two different calculations should produce the same result. This would be true if all the calls were in a single thread or there were one in each rank, as it is for MPI_Init.

The "expview -m min, max, average" view can expose load imbalance by showing when the minimum and maximum time for asynchronous MPI functions have large differences. This situation indicates that some of the MPI asynchronous functions ran quickly (low minimum times) but some had to wait a long time to get started (large maximum times). Many times the function calls that ran quickly were the last to arrive and actually are from ranks that are not running as well as the others, causing load imbalance and delays to the overall job execution speed. These ranks show better performance numbers in terms of the MPI function time, but that is only because they were the last to arrive at the internal barrier point and did not have to wait as long as the other MPI functions that arrived sooner, but had to wait for the other ranks to finally arrive.

7.3 MPI Tracing Experiments (mpip)

7.3.1 MPI Tracing Experiments (mpip) performance data gathering

Much of this information is described above in the main MPI Tracing Experiments section, but for completeness, this is the convenience script description for running the MPI specific (mpi, mpit, mpip) tracing experiments.

> ossmpip “srun –N 4 –n 32 smg2000 –n 50 50 50” [default | <list MPI functions> | mpi_category]

If the mpi_category or a list of categories is given to the ossmpi command, then only those the MPI function corresponding to that category will be traced. The MPI categories are defined according to the table below.

MPI Category	Argument
All MPI Functions	all
Collective Communicators	collective_com
Persistent Communicators	persistent_com
Synchronous Point to Point	synchronous_p2p
Asynchronous Point to Point	asynchronous_p2p
Process Topologies	process_topologies
Groups Contexts Communicators	graphs_contexts_comms
Environment	environment
Datatypes	datatypes
MPI File I/O	fileio

7.3.2 MPI Tracing Experiments (mpip) performance data viewing with CLI

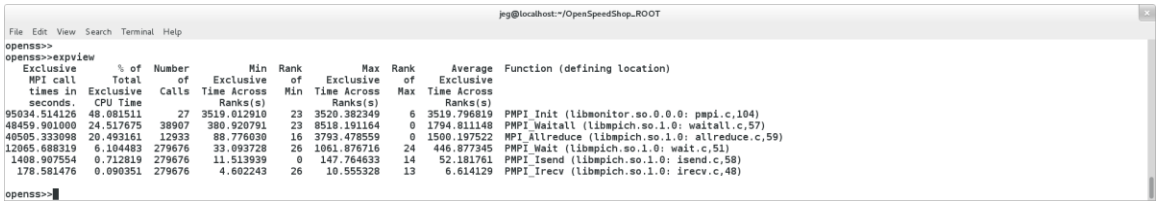
To launch the CLI on any experiment, use “openss –cli –f <database name>“.

The following table describes the header and column data definitions for the default MPI experiment views.

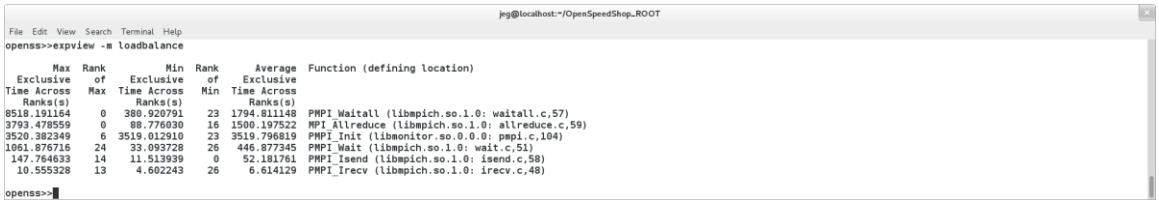
Column Name	Column Definition
Exclusive MPI Call Time	Aggregated total exclusive time spent in the MPI function corresponding to this row of data.
% of MPI Time	Percentage of exclusive MPI time spent in the MPI function corresponding to this row of data relative to the total MPI time for all the MPI functions.
Number of Calls	Total number of calls to the MPI function corresponding to this row of data.
Min MPI Call Time Across Ranks	The minimum time that a rank or ranks, across all ranks, spent in the corresponding MPI function.
Rank of Min	The number of the rank that had the minimum time spent in the MPI function across all the ranks of the application.

Max MPI Call Time Across Ranks	The maximum time that a rank or ranks, across all ranks, spent in the corresponding MPI function.
Rank of Max	The number of the rank that had the maximum time spent in the MPI function across all the ranks of the application.
Average MPI Call Time Across Ranks	The average for the default view is the total amount of time for all the calls to a function divided by the total number of ranks. Thus it is the average time that each rank spends in the function. As such, it is comparable to the Max and Min of a rank that is in the same report.

This is an example of the CLI default view for the MPI (mpip) experiments.



This is an example of the CLI load balance view for the MPI (mpip) experiment. This view shows the minimum, maximum, and average time per rank for each function and the rank that represents the maximum time and minimum time. Note that there may be more ranks that have the same maximum and minimum time per rank.



This is an example of the ability to compare performance information at the rank level in the CLI. Here we show a comparison on the exclusive time metric for rank 0 and rank 23. These ranks were show to be the ranks that had the maximum and minimum values for MPI_Waitall above. One could also use the expview -r 0 and expview -r 23 to see the times for just those ranks.

```
jeg@localhost:~/OpenSpeedShop_ROOT
File  Edit  View  Search  Terminal  Help
openss>>expcompare -r0,23 -mtime

     -r 0,       -r 23,  Function (defining location)
  Exclusive    Exclusive
   MPI call     MPI call
   times in     times in
   seconds.     seconds.
8518.191164   380.920791  PMPI_Waitall (libmpich.so.1.0: waitall.c,57)
3793.478559   572.198026  MPI_Allreduce (libmpich.so.1.0: allreduce.c,59)
3519.665395  3519.012910  PMPI_Init (libmonitor.so.0.0.0: pmpi.c,104)
 699.083580   363.937877  PMPI_Wait (libmpich.so.1.0: wait.c,51)
  11.513939    28.868632  PMPI_Isend (libmpich.so.1.0: isend.c,58)
   5.608623     5.892431  PMPI_Irecv (libmpich.so.1.0: irecv.c,48)
openss>>
```

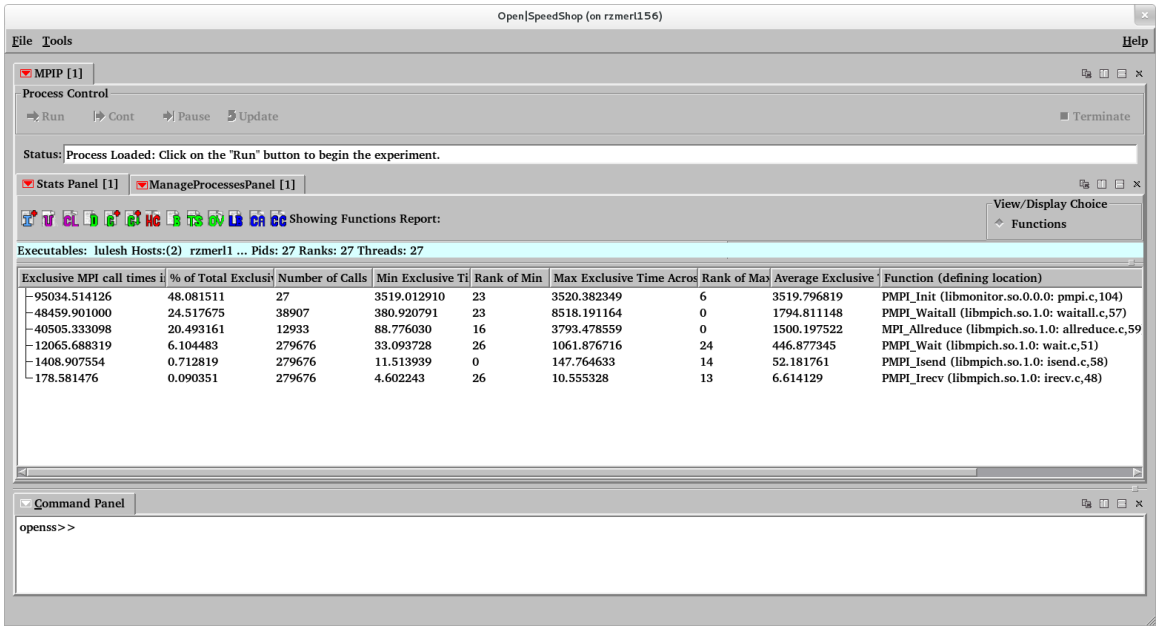
Here we show the top two call paths in the program that took the most time (with respect to MPI function calls).

```
jeg@localhost:~/OpenSpeedShop_ROOT
File  Edit  View  Search  Terminal  Help
openss>>expview -v calltrees,fullstack mpip2

   Exclusive       % of  Number        Min  Rank        Max  Rank    Average  Call Stack Function (defining location)
    MPI call       Total      of  Exclusive    of  Exclusive    of  Exclusive
    times in   Exclusive   Calls       Time   Min       Time   Max       Time
    seconds.    CPU Time            Across           Across           Across
                                   Ranks(s)         Ranks(s)         Ranks(s)
                                                                     _start (lulesh)
                                                                     > @ 562 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
                                                                     >> @ 258 in __libc_start_main (libc-2.12.so: libc-start.c,96)
                                                                     >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
                                                                     >>>> @ 5340 in main (lulesh: lulesh.cc,5333)
95034.514126  48.081511      27                                     >>>>> @ 104 in PMPI_Init (libmonitor.so.0.0.0: pmpi.c,104)
                                                                     _start (lulesh)
                                                                     > @ 562 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
                                                                     >> @ 258 in __libc_start_main (libc-2.12.so: libc-start.c,96)
                                                                     >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
                                                                     >>>> @ 2381 in main (lulesh: lulesh.cc,5333)
40505.333098  20.493161   12933                                     >>>>> @ 59 in MPI_Allreduce (libmpich.so.1.0: allreduce.c,59)

openss>>
```

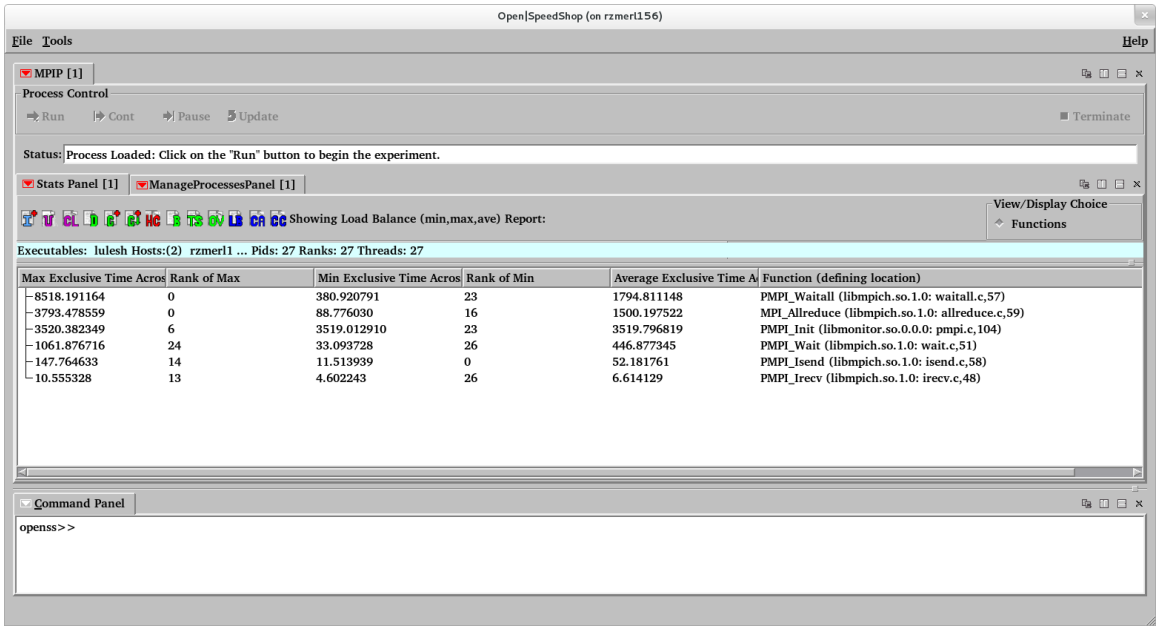
7.3.3 MPI Tracing Experiments (mpip) performance data viewing with GUI

To launch the GUI on any experiment, use “openss –f <database name>“.

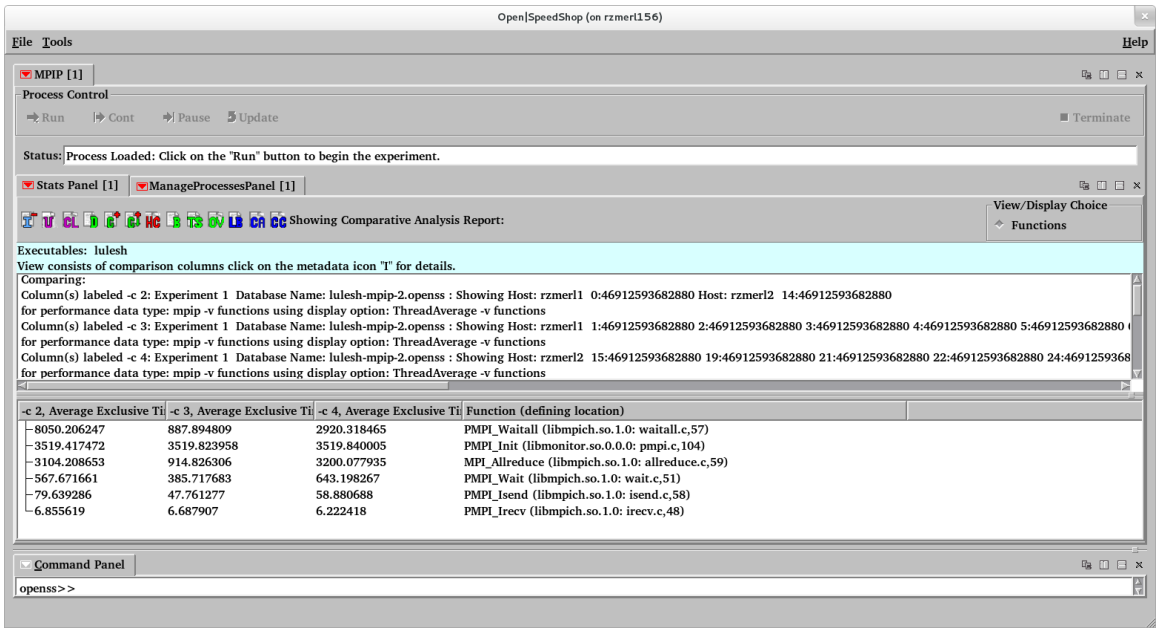
This is an example of the GUI default view for the MPI (mpip) experiment.



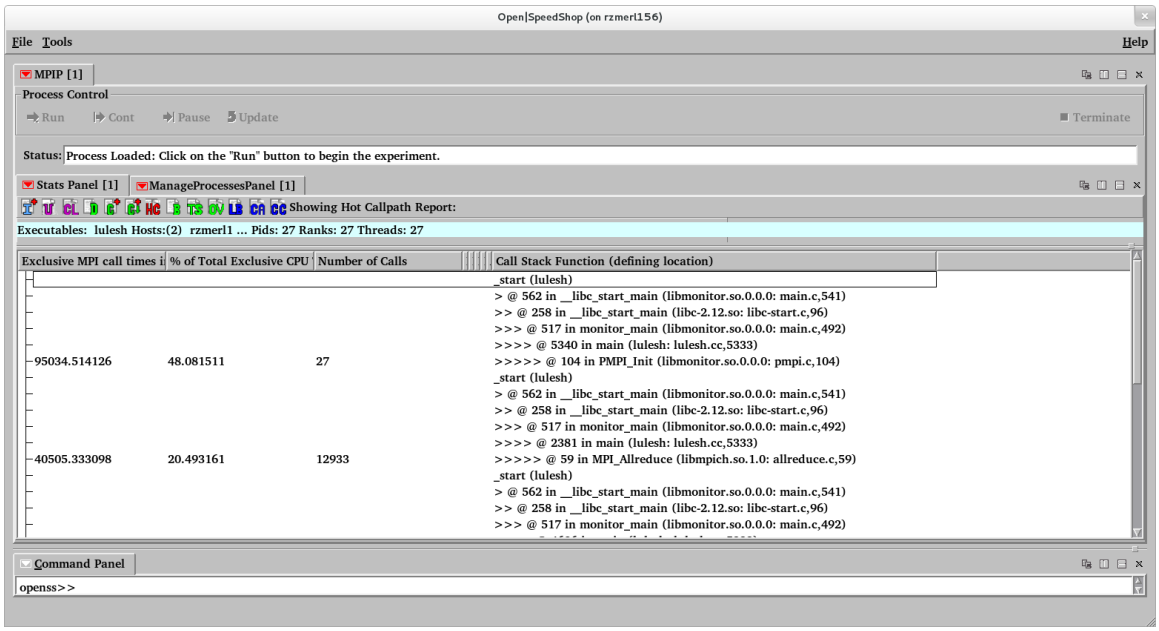
The following view shows the load balance for this execution of lulesh on 27 ranks.



This view shows the cluster analysis view for this run of lulesh on 27 ranks. The cluster analysis view groups like performing ranks together as a means of locating groups of ranks that are outliers with respect to the other ranks.



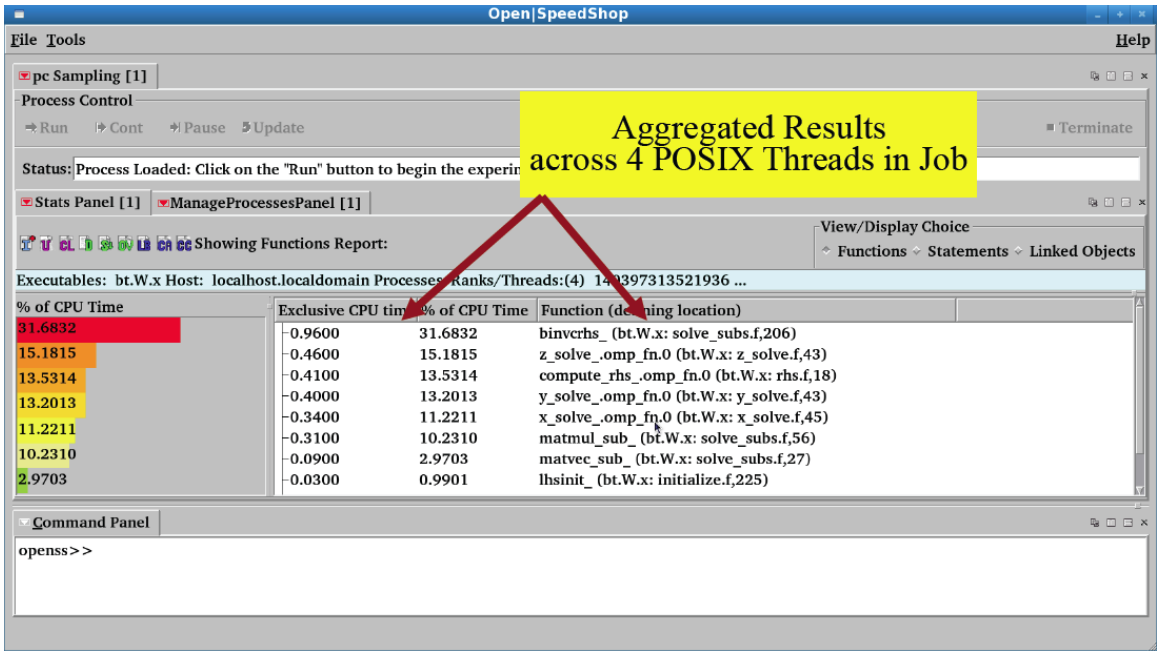
This view shows the hot call paths in the application.



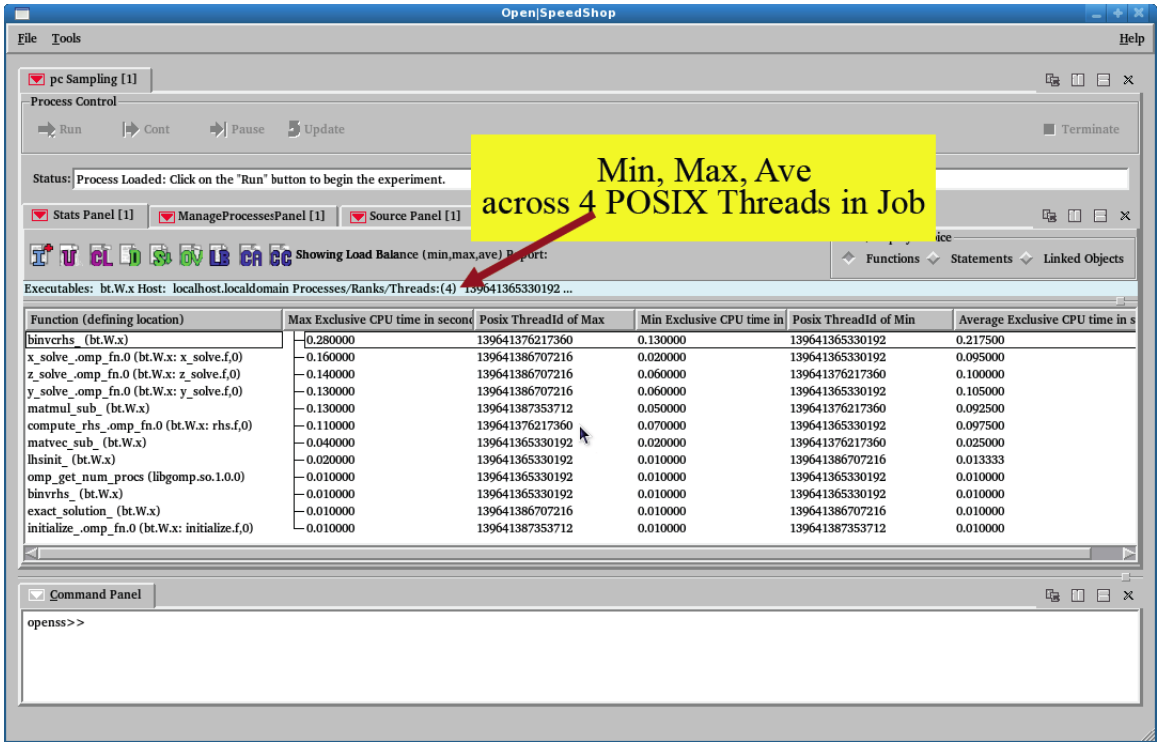
8 Threading Analysis Section

We just did an experiment that uses MPI but we can do a similar analysis on applications that use threads. To analyze a threaded application first, we can run the pcsamp experiment to get an overview, then look at the load balance view to detect if there are any widely varying values and finally do cluster analysis to find any outliers.

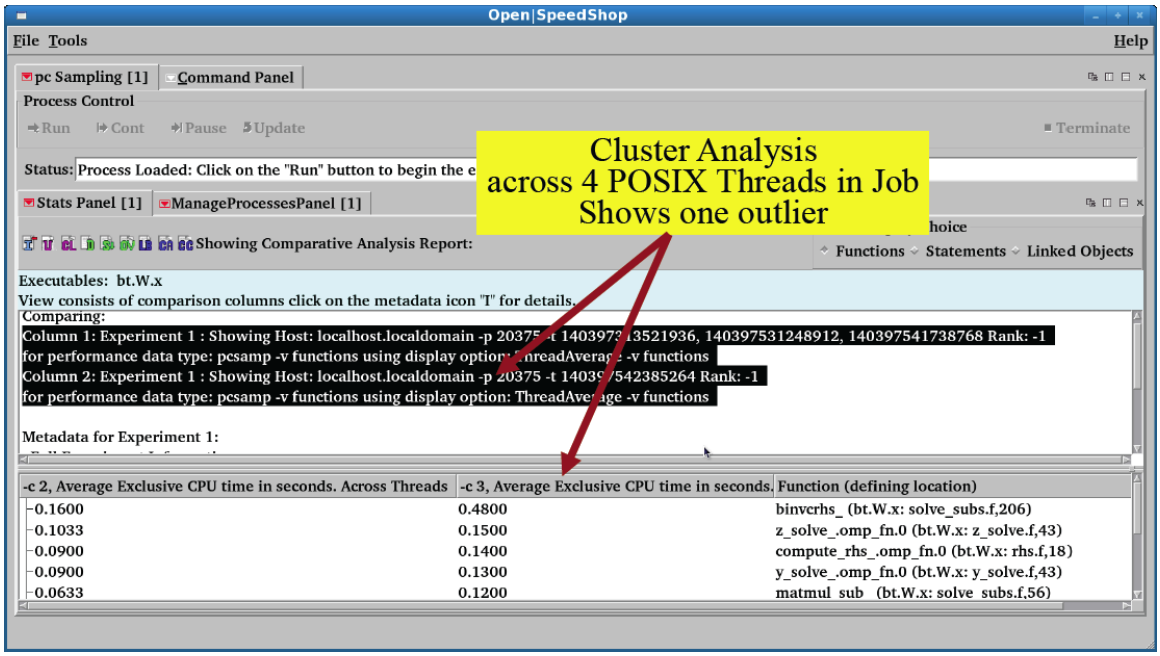
The image below shows the default view for an application with 4 threads, the information displayed is the aggregated total from all threads.



Next we see the load balance view based on functions.



Then we look at a cluster analysis view based on functions.



8.1 Threading Specific Experiment (pthreads)

An experiment specific to tracking POSIX thread function calls and analyzing those calls is also available in O|SS. The experiment is called pthreads and it traces several POSIX thread related functions. Like all the other tracing experiments, number of calls, time spent in each function, the call paths to each POSIX thread function, and an event-by-event trace is available. Load balance and cluster analysis features are also available.

8.1.1 Threading Specific (pthreads) experiment performance data gathering (osspthreads)

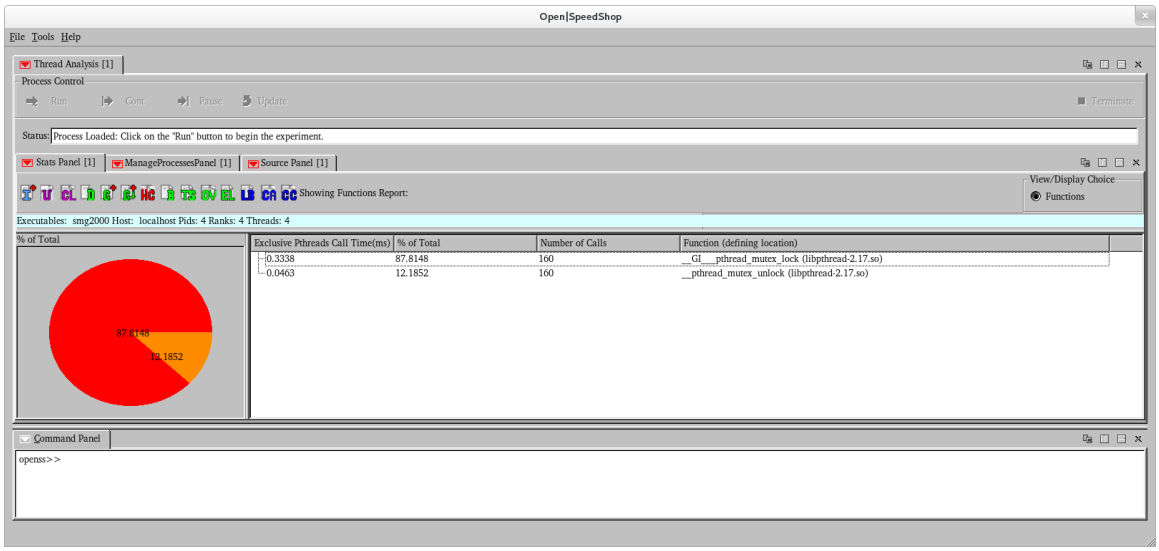
To run the pthreads experiment use the osspthreads convenience script placing how you would normally run the application in quotes, as shown below:

```
osspthreads "mpirun -np 4 ./smg2000 -n 15 15 15"
```

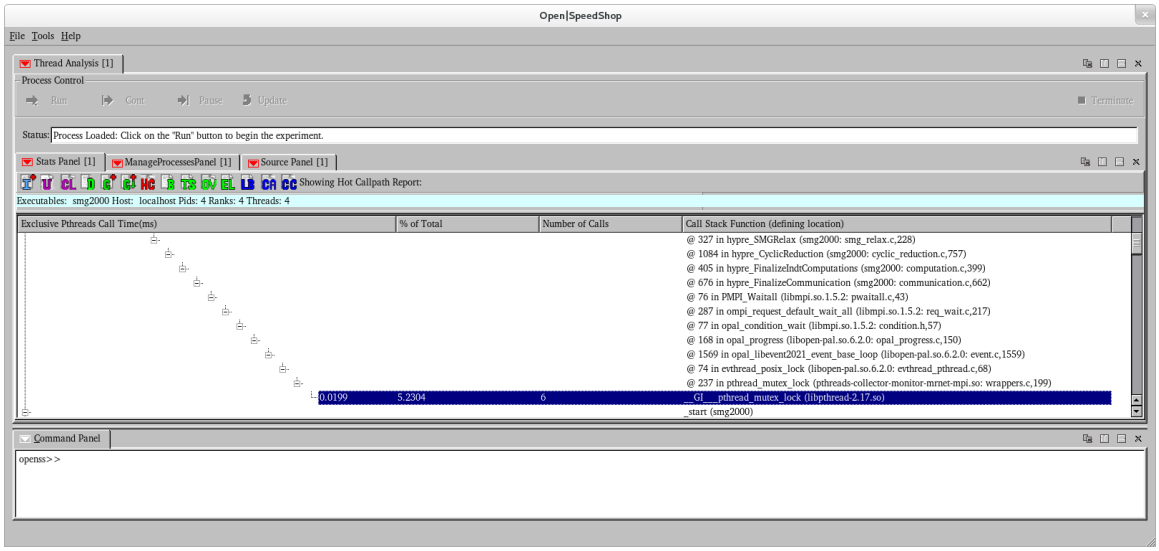
8.1.2 Threading Specific (pthreads) experiment performance data viewing with GUI

To launch the GUI on any experiment, use “openss –f <database name>“.

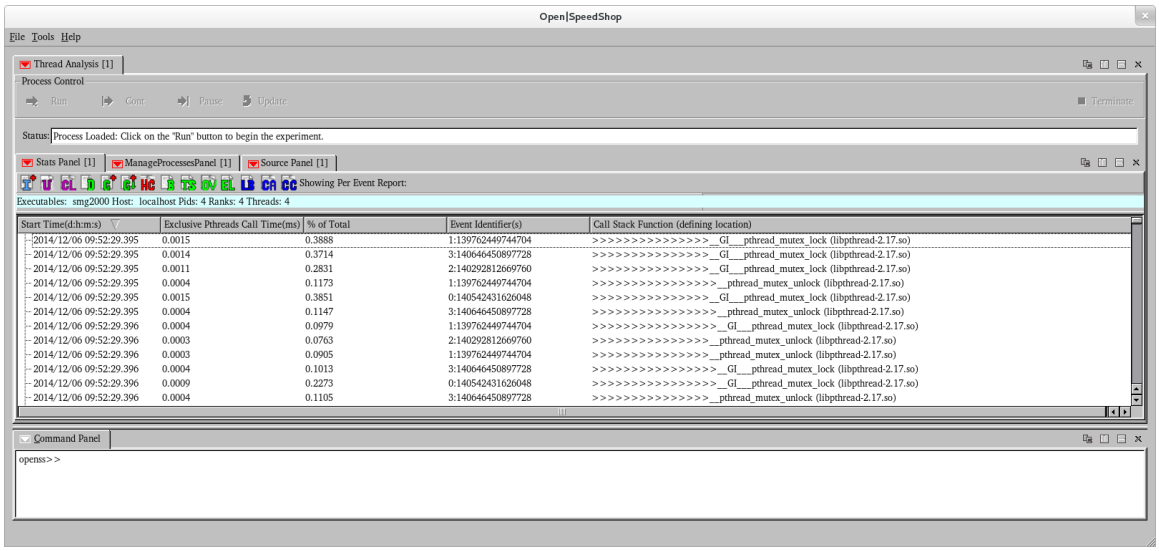
Three pthreads experiment views follow. The first is the default pthreads experiment view, which lists the POSIX, thread function routines that were called in the application being monitored, the number of times they were called, and the time spent in each function.



The second view (below) shows the top five, time taking POSIX thread function call paths through the application monitored.



The third view is an event list view, which is a chronological POSIX, thread call list. This view shows each POSIX thread function call in the order they occurred: showing the rank and thread the call originated from, the time spent in the POSIX thread function call event, and the percentage of the total time that represents.



8.1.3 Threading Specific (pthreads) experiment performance data viewing with CLI

To launch the CLI on any experiment, use "openss –cli –f <database name>".

```
openss>>[openss]: The restored experiment identifier is:  -x 1
openss>>expview

Exclusive    % of      Number  Function (defining location)
Pthreads    Total        of
  Call                  Calls
Time(ms)
 0.3338     87.8148     160  __GI___pthread_mutex_lock (libpthread-2.17.so)
 0.0463     12.1852     160  __pthread_mutex_unlock (libpthread-2.17.so)

openss>>expview -v fullstack pthreads3

Exclusive    % of   Number  Call Stack Function (defining location)
Pthreads    Total     of
  Call                Calls
Time(ms)
                  _start (smg2000)
                  > @ 562 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
                  >>__libc_start_main (libc-2.17.so)
                  >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
                  >>>> @ 512 in main (smg2000: smg2000.c,21)
                  >>>>> @ 69 in HYPRE_StructSMGSolve (smg2000: HYPRE_struct_smg.c,64)
                  >>>>>> @ 225 in hypre_SMGSolve (smg2000: smg_solve.c,57)
                  >>>>>>> @ 325 in hypre_SMGRelax (smg2000: smg_relax.c,228)
                  >>>>>>>> @ 225 in hypre_SMGSolve (smg2000: smg_solve.c,57)
                  >>>>>>>>> @ 327 in hypre_SMGRelax (smg2000: smg_relax.c,228)
                  >>>>>>>>>> @ 1084 in hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
                  >>>>>>>>>>> @ 405 in hypre_FinalizeIndtComputations (smg2000: computation.c,399)
                  >>>>>>>>>>>> @ 676 in hypre_FinalizeCommunication (smg2000: communication.c,662)
                  >>>>>>>>>>>>> @ 76 in PMPI_Waitall (libmpi.so.1.5.2: pwaitall.c,43)
                  >>>>>>>>>>>>>> @ 287 in ompi_request_default_wait_all (libmpi.so.1.5.2: req_wait.c,217)
                  >>>>>>>>>>>>>>> @ 77 in opal_condition_wait (libmpi.so.1.5.2: condition.h,57)
                  >>>>>>>>>>>>>>>> @ 168 in opal_progress (libopen-pal.so.6.2.0: opal_progress.c,150)
                  >>>>>>>>>>>>>>>>> @ 1569 in opal_libevent2021_event_base_loop (libopen-pal.so.6.2.0:
event.c,1559)
                  >>>>>>>>>>>>>>>>>> @ 74 in evthread_posix_lock (libopen-pal.so.6.2.0: evthread_pthread.c,68)
```

```
                >>>>>>>>>>>>>>>>>>> @ 237 in pthread_mutex_lock (pthreads-collector-monitor-mrnet-mpi.so:
wrappers.c,199)
 0.0199  5.2304      6 >>>>>>>>>>>>>>>>>>>>__GI___pthread_mutex_lock (libpthread-2.17.so)
 ...
 ...

openss>>expview -mloadbalance

    Max      Rank      Min       Rank   Average        Function (defining location)
Exclusive    of     Exclusive     of    Exclusive
Pthreads    Max      Pthreads    Min    Pthreads
call time            call time         call time
    in                  in             in
seconds.            seconds.          seconds.
 Across             Across            Across
Ranks(ms)          Ranks(ms)         Ranks(ms)
 0.1084     3        0.0717     2       0.0835      __GI___pthread_mutex_lock (libpthread-2.17.so)
 0.0120     3        0.0112     1       0.0116      __pthread_mutex_unlock (libpthread-2.17.so)
```

8.2 OpenMP Related Performance Analysis

8.2.1 OpenMP Thread Wait Detection using OMPT interface

O|SS, if built with the OMPT enhanced openMP runtime library will detect openMP thread wait time. In general, OpenMP support in O|SS is available in two forms.

8.2.1.1 Augmentation of Open|SpeedShop sampling experiments

The first form is the integration of the information gathered from the OpenMP runtime, through the new OMPT tools interface, into the existing displays and experiments. We are currently doing this by aggregating the information from the runtime into "pseudo functions" and then listing them as part of the standard profile (without any details of what is actually executed in the runtime). An example of this is below, which shows thread idle time (as part of the pseudo function **THREAD_IDLE** and barrier time as part of **THREAD_WAIT_BARRIER)**. Other states in the runtime would be shown similarly.

```
openss>>expview
Exclusive % of Function (defining location) CPU time CPU in Time seconds.
453.0900 14.4423 CalcFBHourglassForceForElems() (lulesh2.0: lulesh.cc,745)
325.5600 10.3773 IntegrateStressForElems() (lulesh2.0: lulesh.cc,526)
312.5800  9.9635 EvalEOSForElems(Domain&, double*, int, int*, int) (lulesh2.0: lulesh.cc,2236)
306.6100  9.7732 LagrangeNodal(Domain&) (lulesh2.0: lulesh.cc,1253)
230.6600  7.3523 CalcKinematicsForElems(Domain&, double*, double, int) (lulesh2.0: lulesh.cc,1535)
160.3400  5.1109 THREAD_IDLE (pcsamp-collector-monitor-mrnet-mpi.so: collector.c,477)
156.6800  4.9942 psm_mq_ipeek (libpsm_infinipath.so.1.14)
150.4100  4.7943 ips_ptl_poll (libpsm_infinipath.so.1.14)
132.9100  4.2365 CalcElemVolumeDerivative(double*, double*, double*, double const*, double const*, double
const*) (lulesh2.0: lulesh.cc,658)
105.9600  3.3775 CalcMonotonicQGradientsForElems(Domain&, double*) (lulesh2.0: lulesh.cc,1643)
 99.8600  3.1831 __pthread_cond_signal (libpthread-2.12.so: pthread_cond_signal.S,38)
 77.6300  2.4745 __GI_vfprintf (libc-2.12.so: vfprintf.c,201)
```

77.2600 2.4627 sbrk (libc-2.12.so: sbrk.c,35)
60.2000 1.9189 CalcMonotonicQRegionForElems(Domain&, int, double*, double) (lulesh2.0: lulesh.cc,1792)
41.7800 1.3317 main (lulesh2.0: lulesh.cc,2690)
34.1000 1.0869 **THREAD_WAIT_BARRIER** (pcsamp-collector-monitor-mrnet-mpi.so: collector.c,501)
30.6000 0.9754 __psmi_poll_internal (libpsm_infinipath.so.1.14)
25.2300 0.8042 _IO_default_xsputn_internal (libc-2.12.so: genops.c,452)

What does the OMPT interface usage in O|SS allow the users of O|SS to do?

O|SS applies the OMPT API blame callbacks for ompt_event_thread_idle, ompt_event_thread_barrier and ompt_event_thread_wait_barrier to samples taken in the OpenMP library that otherwise would be shown as __kmp_barrier, __kmp_wait_sleep, etc. in the Intel libiomp5 library. We use the libiomp5 library with the OMPT API enabled at runtime to do this for all OpenMP codes run with the pcsamp, usertime and hardware counter based experiments. The user can then see the sample time per thread for idle, barrier, and wait_barrier. The user can also use the loadbalance metric to see the min, max, average of these blame events or use the expcompare across all threads to see individual metrics in comparison to each other.

With respect to the barrier symbols, samples taken when a thread is waiting at a barrier are inclusive to total barrier time. I.e. adding barrier and wait_barrier metrics is equal to the total barrier time.

Essentially these blame metrics as used in the O|SS sampling experiments inform the user the time a thread is idle and the time spent at a barrier (including waiting at a barrier).

Here is a debug sequence to show that OpenMP thread 2 enters a barrier and then enters a wait_barrier. Any sample taken before wait_barrier_end should be blamed on the wait_barrier (it is in O|SS, however O|SS did not blame any samples that may have been just part of the barrier time itself).

[2] CBTF_ompt_cb_barrier_begin parallelID:17 taskID:131 begin time:1460390626061260754
[2] CBTF_ompt_cb_wait_barrier_begin parallelID:17 taskID:131
[2] CBTF_ompt_cb_wait_barrier_end: parallelID:17 taskID:131
[2] CBTF_ompt_cb_barrier_end: parallelID:17 taskID:131 total barrier time:264734
[2] CBTF_ompt_cb_barrier_begin parallelID:17 taskID:131 begin time:1460390626061325546
[2] CBTF_ompt_cb_barrier_end: parallelID:17 taskID:131 total barrier time:269096

Here is the case where no wait_barrier happened while the OpenMP thread 2 was at a barrier.
Any sample taken in this condition should be blamed on just the barrier.

[2] CBTF_ompt_cb_barrier_begin parallelID:15 taskID:117 begin time:1460390626061038145
[2] CBTF_ompt_cb_barrier_end: parallelID:15 taskID:117 total barrier time:196470

If one adds barrier and wait_barrier we would have total samples taken at a barrier and wait_barrier is just the samples within that barrier when there is a thread_barrier_wait

condition.

Here is an example from lulesh sequential OpenMP case:

```
openss>>expview -f OMPT* -m time
Exclusive  Function (defining location)
 CPU time
     in
 seconds.
 1.460000  THREAD_IDLE (pcsamp-collector-monitor-mrnet.so: collector.c,99)
 0.470000  THREAD_WAIT_BARRIER (pcsamp-collector-monitor-mrnet.so: collector.c,129)
 0.020000  THREAD_BARRIER (pcsamp-collector-monitor-mrnet.so: collector.c,113)

openss>>expcompare -f OMPT* -m time -t0:4

   -t 0,     -t 2,     -t 3,     -t 4,  Function (defining location)
Exclusive  Exclusive  Exclusive  Exclusive
 CPU time   CPU time   CPU time   CPU time
     in         in         in         in
 seconds.   seconds.   seconds.   seconds.
 0.360000   0.030000   0.070000   0.010000  THREAD_WAIT_BARRIER (pcsamp-collector-monitor-
mrnet.so: collector.c,129)
 0.000000   0.500000   0.400000   0.560000  THREAD_IDLE (pcsamp-collector-monitor-mrnet.so:
collector.c,99)
 0.000000   0.000000   0.010000   0.010000  THREAD_BARRIER (pcsamp-collector-monitor-
mrnet.so: collector.c,113)
openss>>expview -f OMPT* -m time -t3

Exclusive  Function (defining location)
 CPU time
     in
 seconds.
 0.400000  THREAD_IDLE (pcsamp-collector-monitor-mrnet.so: collector.c,99)
 0.070000  THREAD_WAIT_BARRIER (pcsamp-collector-monitor-mrnet.so: collector.c,129)
 0.010000  THREAD_BARRIER (pcsamp-collector-monitor-mrnet.so: collector.c,113)
```

What this shows the user is that most of the barrier samples were taken when the thread were waiting at the barrier. The THREAD_BARRIER and THREAD_WAIT_BARRIER symbols replace samples that would have appeared as __kmp_barrier (or possibly __kmp_join_barrier) in the latest libiomp5. The THREAD_IDLE samples replace __kmp_wait_sleep in the real libiomp5.

The above applies to pcsamp, usertime, and the hwc* collectors. Essentially telling the user the time a thread is idle and the time spent at a barrier (including waiting at a barrier).

One could infer from the example above with the addition of THREAD_BARRIER that most of the barrier time for thread 2 was spent waiting at the barrier.

Using the usertime experiment on an OpenMP application can help to pinpoint where in the source the wait barrier time is coming from. For example:

```
openss>>expview
Exclusive  Inclusive      % of  Function (defining location)
 CPU time   CPU time     Total
     in         in  Exclusive
```

```
 seconds.  seconds.  CPU Time
23.200000  23.200000  38.648263  THREAD_IDLE (usertime-collector-monitor-mrnet.so:
collector.c,122)
13.142857  13.142857  21.894336  MAIN__.omp_fn.2 (stress_omp: stress_omp.f,179)
12.885714  12.885714  21.465969  MAIN__.omp_fn.5 (stress_omp: stress_omp.f,227)
 4.742857   4.742857   7.901000  THREAD_WAIT_BARRIER (usertime-collector-monitor-mrnet.so:
collector.c,150)
 2.000000  11.771428   3.331747  MAIN__ (stress_omp: stress_omp.f,1)
 1.257143   1.257143   2.094241  __kernel_cosf (libm-2.12.so: k_cosf.c,45)
 1.085714   1.085714   1.808663  __ieee754_rem_pio2f (libm-2.12.so: e_rem_pio2f.c,108)
```

Here we see the call path that points to the source lines that result in the thread waiting in the barrier.

```
openss>>expview -vfullstack -f THREAD_WAIT_BARRIER  usertime1

Exclusive  Inclusive      % of  Call Stack Function (defining location)
 CPU time   CPU time     Total
     in        in  Exclusive
 seconds.   seconds.   CPU Time
                       _start (stress_omp)
                       > @ 556 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
                       >>__libc_start_main (libc-2.12.so)
                       >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
                       >>>>main (stress_omp)
                       >>>>> @ 227 in MAIN__ (stress_omp: stress_omp.f,1)
                       >>>>>> @ 557 in __kmp_api_GOMP_parallel_end_10_alias (libiomp5.so: kmp_gsupport.c,490)
                       >>>>>>> @ 2395 in __kmp_join_call (libiomp5.so: kmp_runtime.c,2325)
                       >>>>>>>> @ 7114 in __kmp_internal_join (libiomp5.so: kmp_runtime.c,7093)
                       >>>>>>>>> @ 1458 in __kmp_join_barrier(int) (libiomp5.so: kmp_barrier.cpp,1371)
 1.742857   1.742857   2.903379  >>>>>>>>>> @ 150 in THREAD_WAIT_BARRIER (usertime-collector-monitor-mrnet.so: collector.c,150)
```

The significance of these changes is that we now have the following support in O|SS:

- Added idle, barrier, and wait_barrier blame support to all sampling collectors
- Improved naming (THREAD_IDLE, THREAD_BARRIER, THREAD_WAIT_BARRIER) for sample call site.
- Support for building from Intel's libiomp tree to keep us up to data with latest official sources. Should also work with LLVM OpenMP.
- Updated runtime codes to allow running OMPT with gnu/gomp binaries (which means libgomp is replaced with libiomp5 since gomp does not support OMPT directly).
- We also note that the OMPT aspect of OSS works with gcc or g++ generated OpenMP code (and likely clang). No matter what compiler was used to generate the OpenMP code, the Intel libiomp5.so runtime is used for its OMPT API.

With the current OMPT support, there are no distinctions made specific to sub categorization of the idle time or the wait_barrier time.

Looking at the code in question as found in kmp_runtime.c, __kmp_launch_thread has a while loop that set the ompt state to ompt_state_idle, calls __kmp_fork_barrier, then sets the ompt state to a default value of ompt_state_overhead. If __kmp_wait_sleep is called while ompt state is ompt_state_idle when kmp_wait_sleep is called, then the OMPT API considers the thread "idle". In that case, would you consider this "OMP_thread_idle" to be "OMP_thread_fork_wait”?

The other case where __kmp_wait_sleep is entered, with an OMPT state of ompt_state_wait_barrier, that OMPT state is managed by the __kmp_barrier and code __kmp_join_barrier in kmp_runtime.c. The wait and join barrier are both using ompt_state_wait_barrier as coded by the OMPT interface and therefore those are

combined in what O|SS reports for OMP_thread_wait_barrier in the pcsamp example, actually **THREAD_WAIT_BARRIER**.

8.2.2 Open|SpeedShop OpenMP specific profiling experiment (omptp)

The second form is a separate experiment (omptp), which is an OpenMP specific profiling experiment.

8.2.1 OpenMP Specific (omptp) experiment performance data gathering (ossomptp)

To run the OpenMP specific experiment use the ossomptp convenience script placing how you would normally run the application in quotes, as shown below:

```
export OMP_NUM_THREADS=4
ossomptp "mpirun -np 4 ./smg2000 -n 15 15 15"
```

8.2.2 OpenMP Specific (omptp) experiment performance data viewing with GUI

TBD.

8.2.3 OpenMP Specific (omptp) experiment performance data viewing with CLI

The following three CLI examples show the most important ways to view OMPTP experiment data. The default view shows the timing of the parallel regions, idle, barrier, and wait barrier as an aggregate across all threads

```
openss -cli -f ./matmult-omptp-0.openss
openss>>expview

Exclusive  Inclusive      % of  Function (defining location)
 times in   times in     Total
 seconds.   seconds.  Exclusive
                 CPU Time
44.638794  45.255843  93.499987  compute._omp_fn.1 (matmult: matmult.c,68)
 1.744841   1.775104   3.654726  compute_interchange._omp_fn.3 (matmult: matmult.c,118)
 0.701720   0.701726   1.469817  compute_triangular._omp_fn.2 (matmult: matmult.c,95)
 0.652438   0.652438   1.366591  IDLE (omptp-collector-monitor-mrnet.so: collector.c,573)
 0.004206   0.009359   0.008810  initialize._omp_fn.0 (matmult: matmult.c,32)
 0.000032   0.000032   0.000068  BARRIER (omptp-collector-monitor-mrnet.so: collector.c,587)
 0.000000   0.000000   0.000001  WAIT_BARRIER (omptp-collector-monitor-mrnet.so:
collector.c,602
```

This example shows the comparison of exclusive time across all threads for the parallel regions, idle, barrier, and wait barrier.

```
openss>>expcompare -mtime -t0:4

   -t 0,     -t 2,     -t 3,     -t 4,  Function (defining location)
Exclusive  Exclusive  Exclusive  Exclusive
```

```
 times in   times in   times in   times in
 seconds.   seconds.   seconds.   seconds.
11.313892  11.081346  11.313889  10.929668  compute._omp_fn.1 (matmult: matmult.c,68)
 0.443713   0.430553   0.429635   0.440940  compute_interchange._omp_fn.3 (matmult: matmult.c,118)
 0.253632   0.213238   0.164875   0.069975  compute_triangular._omp_fn.2 (matmult: matmult.c,95)
 0.001047   0.001100   0.001095   0.000964  initialize._omp_fn.0 (matmult: matmult.c,32)
 0.000008   0.000008   0.000006   0.000010  BARRIER (omptp-collector-monitor-mrnet.so:
collector.c,587)
 0.000000   0.000000   0.000000   0.000000  WAIT_BARRIER (omptp-collector-monitor-mrnet.so:
collector.c,602)
 0.000000   0.247592   0.015956   0.388890  IDLE (omptp-collector-monitor-mrnet.so: collector.c,573)
```

This example shows the load balance of time across all threads for the parallel regions, idle, barrier, and wait barrier.

```
openss>>expview -mloadbalance

     Max     OpenMp       Min    OpenMp    Average  Function (defining location)
  Exclusive  ThreadId   Exclusive ThreadId   Exclusive
Time Across  of Max   Time Across  of Min  Time Across
   OpenMp              OpenMp
ThreadIds(s)          ThreadIds(s)         ThreadIds(s)

 11.313892      0    10.929668      4    11.159699  compute._omp_fn.1 (matmult: matmult.c,68)
  0.443713      0     0.429635      3     0.436210  compute_interchange._omp_fn.3 (matmult:
matmult.c,118)
  0.388890      4     0.015956      3     0.217479  IDLE (omptp-collector-monitor-mrnet.so:
collector.c,573)
  0.253632      0     0.069975      4     0.175430  compute_triangular._omp_fn.2 (matmult: matmult.c,95)
  0.001100      2     0.000964      4     0.001052  initialize._omp_fn.0 (matmult: matmult.c,32)
  0.000010      4     0.000006      3     0.000008  BARRIER (omptp-collector-monitor-mrnet.so:
collector.c,587)
  0.000000      0     0.000000      0     0.000000  WAIT_BARRIER (omptp-collector-monitor-mrnet.so:
collector.c,602)
```

8.3 Hybrid (openMP and MPI) Performance Analysis

For this tutorial example, we have run O|SS convenience script on the NPB-MZ BT program and created a database file that has 4 ranks each of which has 4 underlying openMP threads.

What this example intends to show is that you can look at hybrid performance first at the MPI level and then can look under the MPI rank to see how the threads are performing. At the MPI level you can see load balance and outliers, then focus on a rank and look at load balance and outliers for the underlying threads. Within a terminal window we enter: ↵

```
openss -f bt-mz.B.4-pcsamp-1.openss↵
```

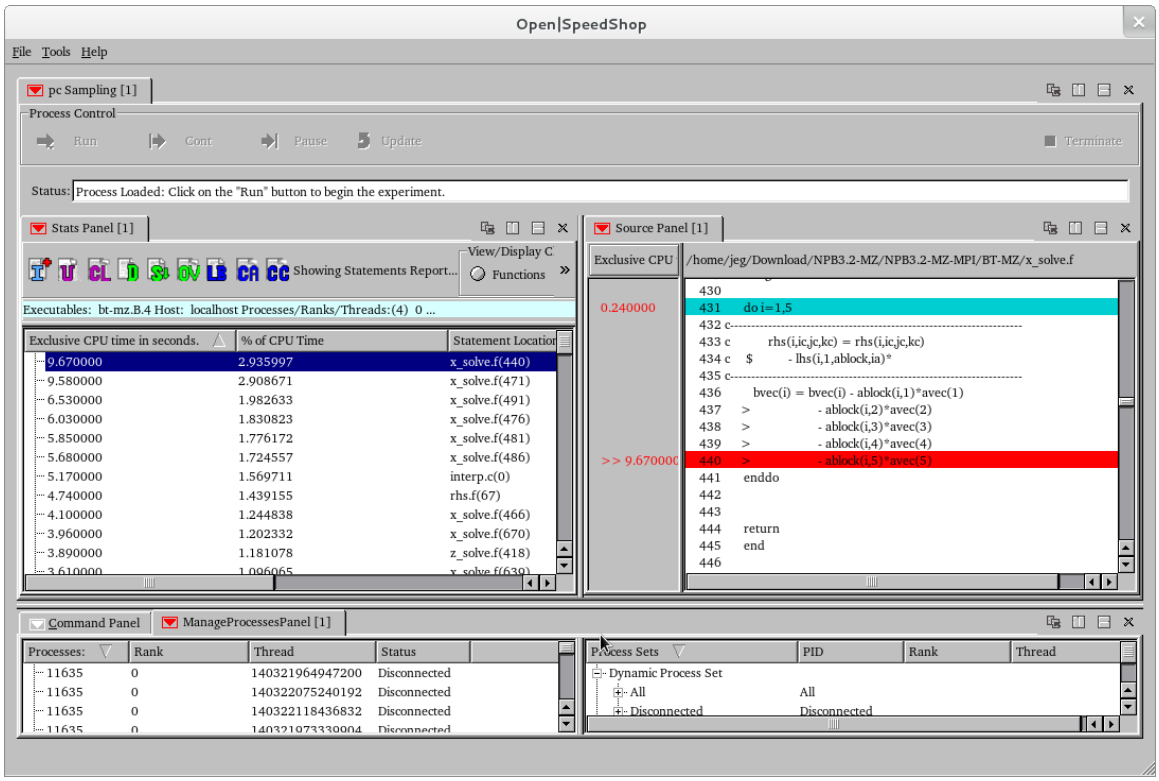
to bring up the O|SS GUI.

In the GUI view below, we display the aggregated results for the application at the statement level granularity. When the default view first comes up the view is at the function level granularity. To switch to the statement level, select the Statements button in the View/Display Choice section on the right hand side of the Stats Panel display and then click the "D" icon for default view. This will switch the Stats Panel view to statement level granularity.

Now the Stats Panel is displaying the statements that took the most time in the application run. For this execution of BT, the statement at line 440 took the most time. By double clicking on the statement, O|SS focuses on the source for that line of the application source and highlights that line.

In the view below, we moved the ManageProcess panel tab to the lower panel and split the upper panel using the vertical splitter icon on the far right side of the original upper panel.

Note: Left mouse down and hold on the panel tab then slide the panel you want to move to another location on the O|SS GUI or off onto other parts of your display.

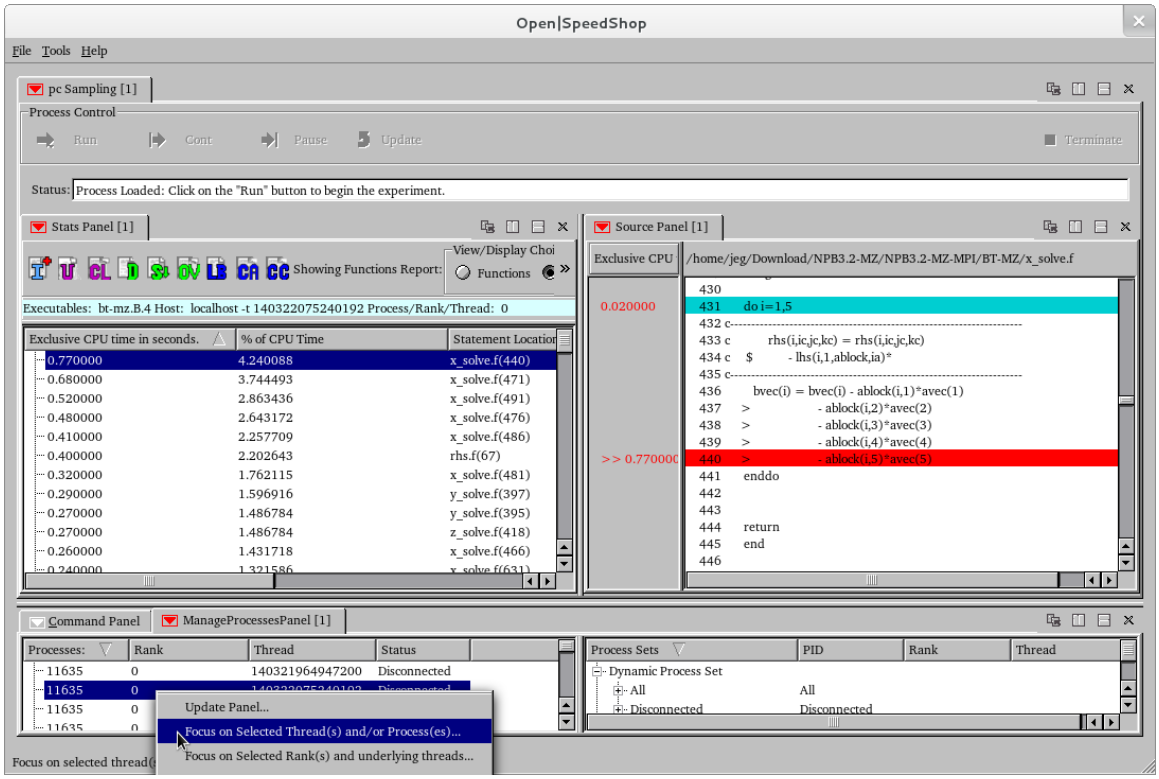


8.3.1 Focus on individual Rank to get Load Balance for Underlying Threads

In the next view (below) we used the ManageProcess panel to highlight one rank and an individual thread within the rank to show only that threads performance

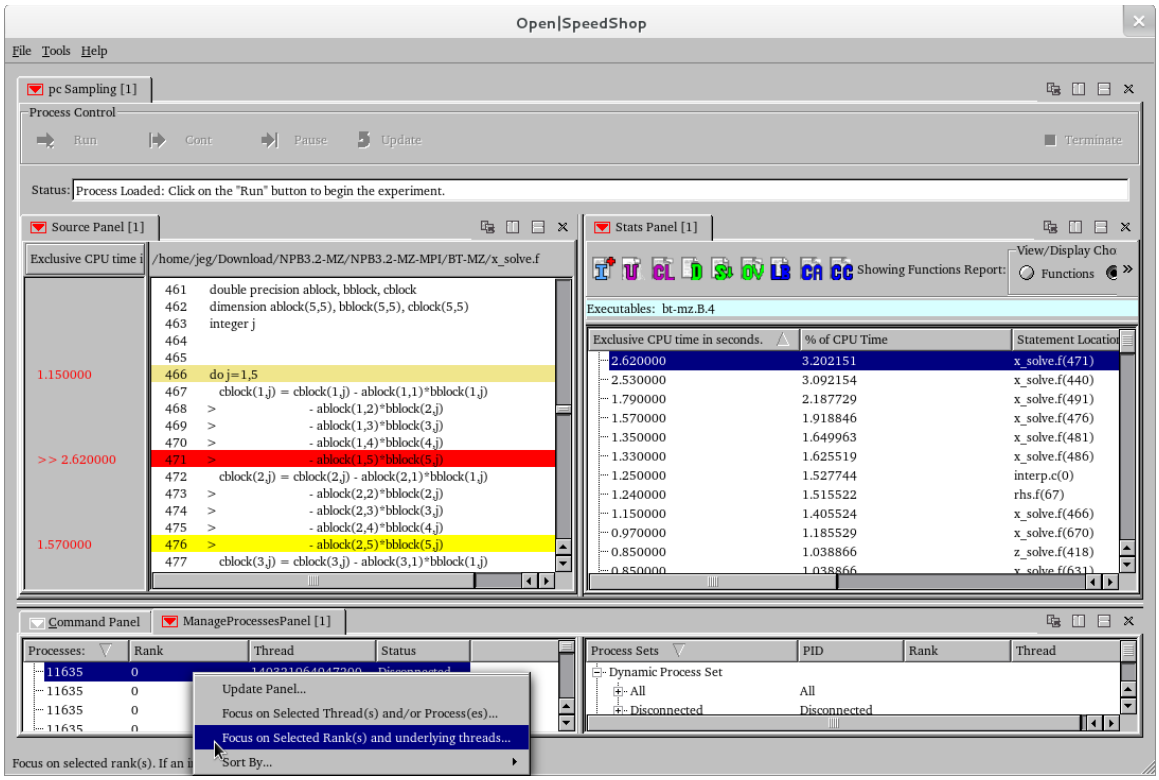
data in the Stats Panel view.

Note: Use the focus on threads and processes Manage Process panel option to focus on individual threads within a rank. Right mouse button down on the Manage Process panel tab to see the options.



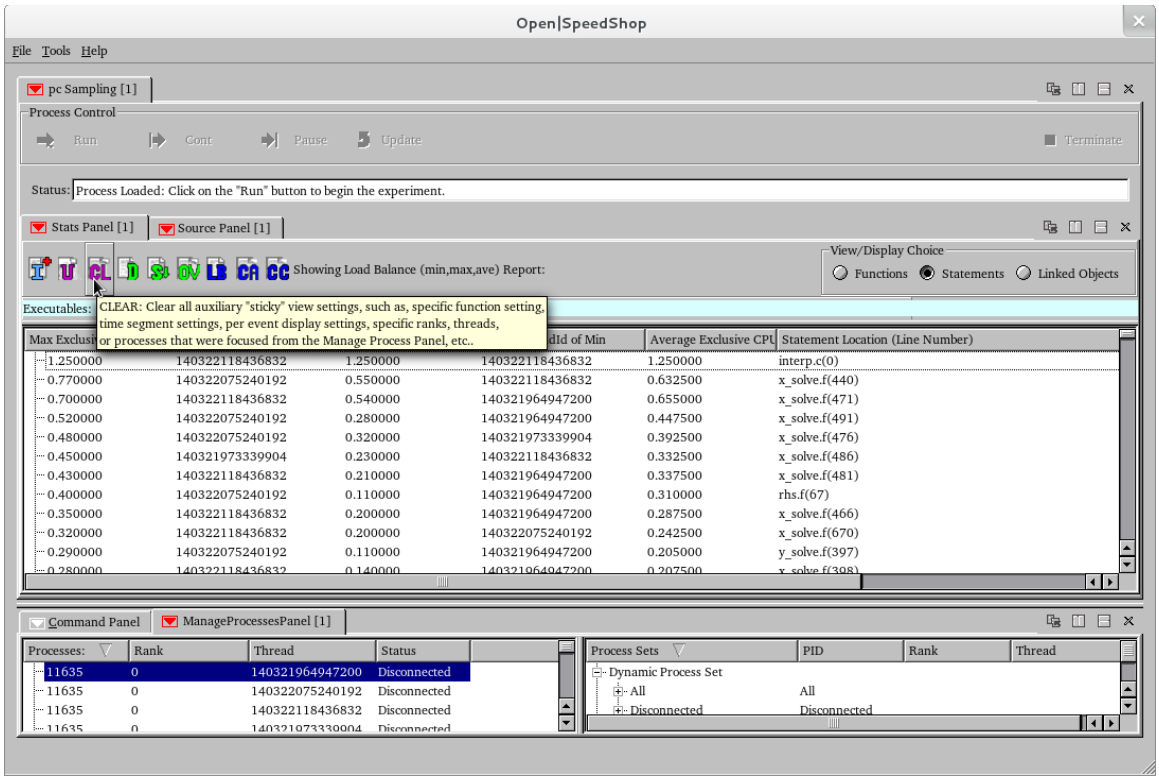
In the next GUI view, we used the ManageProcess panel to highlight one rank to show the performance data from all the threads that are executed under that particular rank in order to see only that performance data in the Stats Panel view.

Note: Use the "focus on selected rank and underlying threads" Manage Process panel option to focus on all the threads within a rank. Right mouse button down on the Manage Process panel tab to see the options.

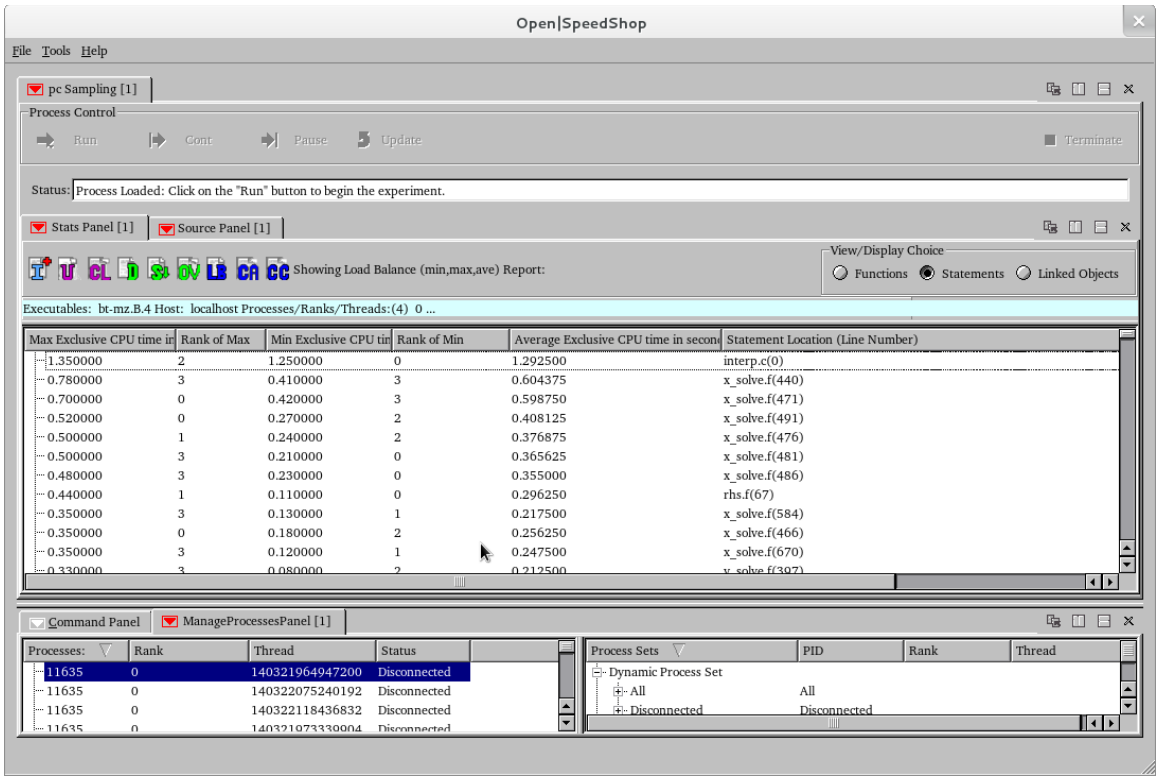


8.3.2 Clearing Focus on individual Rank to get bank to default behavior

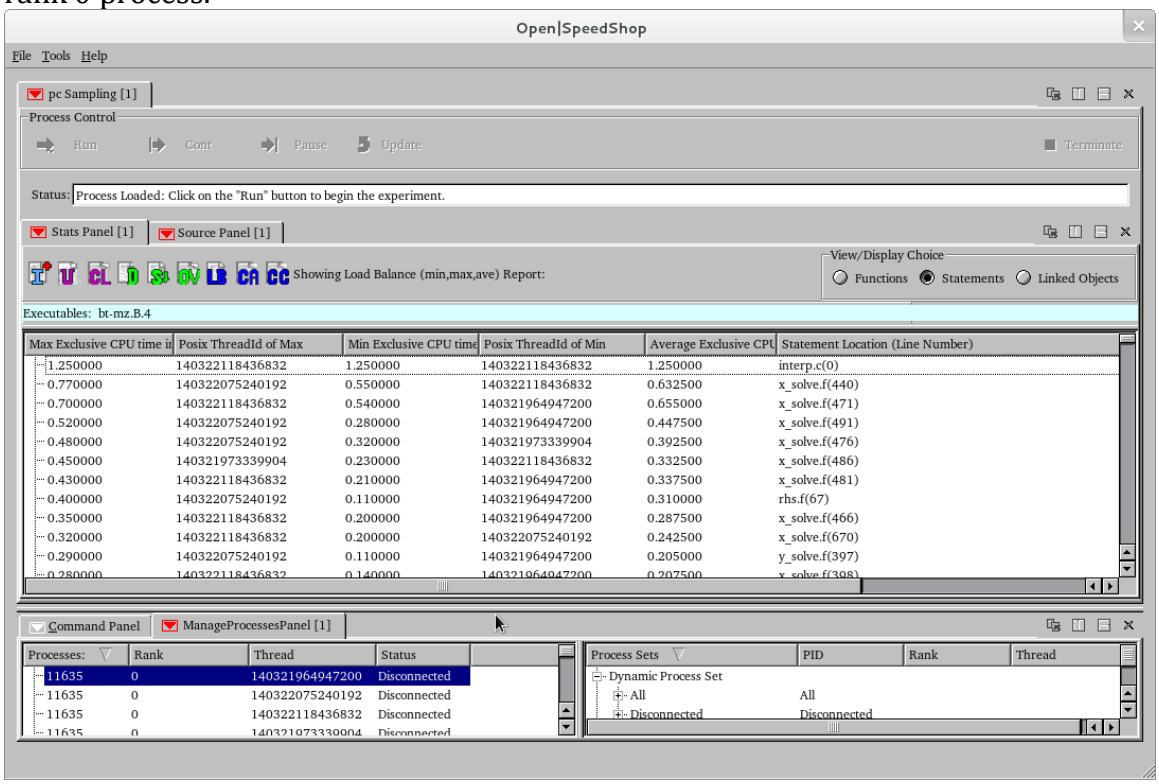
Note: Once you focus on individual or groups of ranks, e.g. venturing away from the default aggregated views, then you need to use the "CL" clear auxiliary setting icon to clear away all the optional selections and get back to looking at the aggregated results again.



After clearing the specific rank and/or thread selections, we can click the "LB" load balance icon and O|SS will display the min, max, average values across all the ranks in the hybrid code. This helps decide if there is imbalance across the ranks of the hybrid application. We can focus on individual ranks to see the balance across the openMP threads that are in an individual rank (next example image).



Here we used the Manage Process panel "Focus on selected rank and underlying threads" menu options to view the load balance across the 4 openMP threads for the rank 0 process.



Please also explore the various options offered via a panel's pull down menu. Clicking on a colored downward-facing arrow or using the Stats Panel icons can access further options. Red icons represent view options, such as updating the data or clearing the view options. The "green" icons correspond to different possible views of the performance data. The "dark blue" icons correspond to analysis options while the "light blue" icon corresponds to information about the experiment. There is context sensitive text that is shown when you hover over the icons.

9 GPU Performance Analysis

9.1 NVIDIA CUDA Analysis Section

The O|SS version with CBTF collection mechanisms supports tracing CUDA events in a NVIDIA CUDA based application. An event-by-event list of CUDA events and the event arguments are gathered and displayed.

9.1.1 NVIDIA CUDA Tracing (cuda) experiment performance data gathering (osscuda)

To run the NVIDIA CUDA experiment, use the osscuda convenience script and specify the CUDA application as an argument. Here is the general format of the osscuda convenience script that is used to gather the NVIDIA CUDA performance information.

```
osscuda “how you run your application normally”
```

In this example, the osscuda script will run the experiment by running the GEMM application and will create an O|SS database file with the results of the experiment. Viewing of the performance information can be done with the GUI or CLI. A default CLI text based report is displayed at the end of the application run.

```
osscuda “mpirun -np 2 -ppn 1 -hosts ccn001,ccn002 ./GEMM”
[openss]: cuda counting all instructions for CPU and GPU.
[openss]: cuda using default periodic sampling rate (10 ms).
[openss]: cuda configuration: "interval=10000000,PAPI_TOT_INS,inst_executed"
Creating topology file for slurm frontend node ccn001 for SLURM_JOB_ID 131
Generated topology file: ./cbtfAutoTopology
Running cuda collector.
Program: mpirun -np 2 -ppn 1 -hosts ccn001,ccn002 ./GEMM
Number of mrnet backends: 2
Topology file used: ./cbtfAutoTopology
executing mpi program: mpirun -np 2 -ppn 1 -hosts ccn001,ccn002 cbtfrun  --mpi  --mrnet  -c
cuda ./GEMM
MPI Task 0/1 starting....
MPI Task 1/1 starting....
Chose device: name='Tesla K40c' index=0
Running single precision test
```

```
Chose device: name='Tesla K40c' index=0
Running single precision test
Running double precision test
Running double precision test
test   atts   units   median   mean   stddev   min   max
DGEMM-N(max)   128   GFlops   57.5899   57.5899   0.259358  57.3306   57.8493
DGEMM-N(mean)   128   GFlops   56.9609   56.9609   0.0587321  56.9022   57.0196
DGEMM-N(median)   128   GFlops   57.3772   57.3772   0.395575  56.9816   57.7728
DGEMM-N(min)   128   GFlops   54.036   54.036   1.59142  52.4445   55.6274
…
…
…
Extreme outliers (>3.0 IQR from 1st/3rd quartile):
None.
default view for ./GEMM-cuda-3.openss

[openss]: The restored experiment identifier is:  -x 1
Performance data spans 0.452563 ms  from 2016/11/09 22:35:07 to 2016/11/09 22:35:07

Exclusive      % of  Exclusive  Function (defining location)
Time (ms)     Total     Count
        Exclusive
           Time
 9.861216  52.062327       200  void RunTest<float>(std::string, ResultDatabase&, OptionParser&)
(GEMM: GEMM.cpp,156)
 9.079958  47.937673       200  void RunTest<double>(std::string, ResultDatabase&, OptionParser&)
(GEMM: GEMM.cpp,156)
```

9.1.2 NVIDIA CUDA Tracing (cuda) experiment performance data viewing with GUI

This section shows the default view for the NVIDIA CUDA experiment for the QTC application. Use the following command to open the GUI to see the GEMM CUDA experiment performance information.

To launch the new beta, cuda focused, GUI on any experiment, use:
"openss-gui –f <database name>".

NOTE: This is a different GUI from the existing O|SS GUI. It is being developed initially focused on providing views for the NVIDIA cuda experiment. Use openss-gui instead of openss to invoke this GUI.

```
openss-gui –f GEMM-cuda-0.openss
```

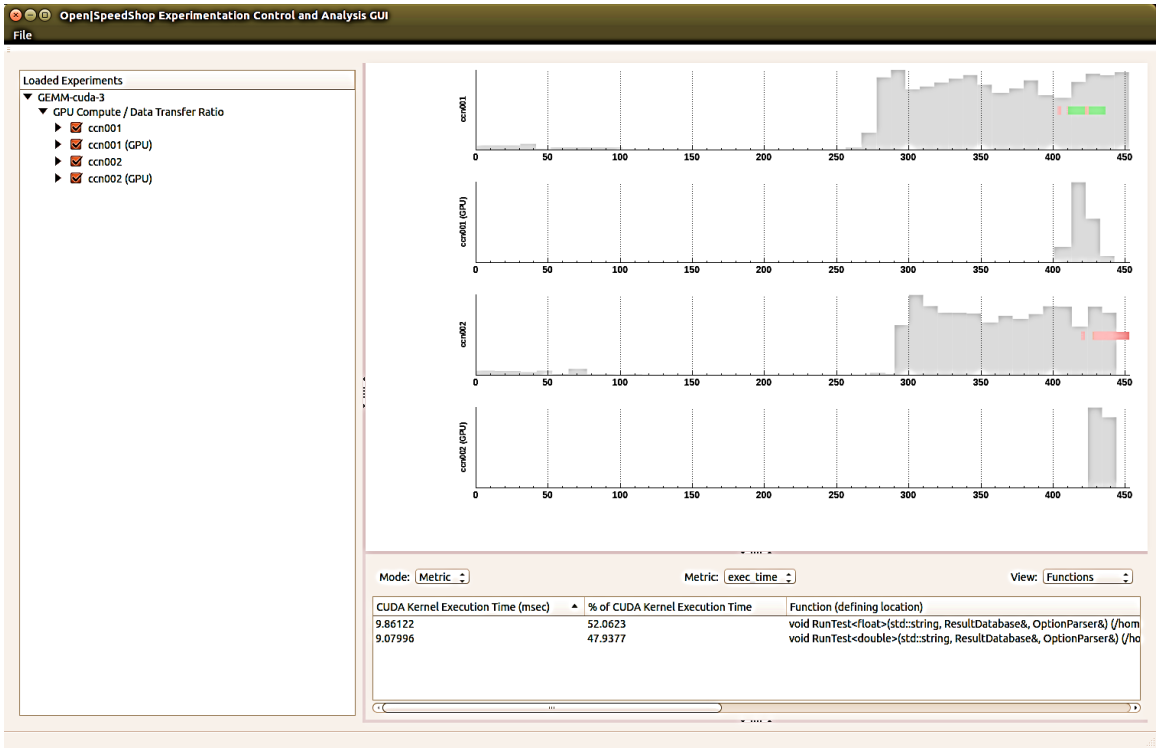
The view below is a default for cuda experiment. A time line tracking the cuda kernel executions are shown with a green color and data transfers to the GPU device and the CPU are shown with a red color. This is too give insight into the relative cost of the transfers versus the actual time spent executing in the kernel. The shaded areas in the timeline represent performance information from the execution

of the application in the GPU and in the CPU. So, one can infer if the GPU and CPU are being fully utilized.

The left panel, labeled “Loaded Experiments” is the area where one will be able to eventually select what process, thread, or rank performance information will be displayed in the timeline and metric value display panel. Currently, it shows information about the application and hosts (processes, threads, ranks) that are involved in this GUI display.

The metric panel (lower right display panel) is where the text based performance information is displayed. There are options based on metric type that control the data being presented in this panel.

A source view panel is also available by opening a GUI pane below the metric panel.



9.1.3 NVIDIA CUDA Tracing (cuda) experiment performance data viewing with CLI

To launch the CLI on any experiment, use “openss –cli –f <database name>“.

The O|SS CLI will report CUDA kernel execution, CUDA data transfer, and CPU/GPU hardware performance counter data gathered by the 'cuda' collector.

The type of data displayed can be controlled through the '-v' options:

Exec	CUDA kernel executions (this is the default)
Xfer	CUDA data transfers
HWPC	CPU/GPU hardware performance counters

The form of the displayed infomation is controlled thru additional '-v' options. For '-v Exec' and '-v Xfer' these additional '-v' options are:

ButterFly	Produces a report summarizing the calls to and from the one or more functions specified by the '-f <function_list>' option. Calling functions will be listed before the named function, and called functions afterwards, by default, unless 'TraceBacks' is specified to reverse this ordering.
CallTree[s]	Produces a calling stack report presented' in calling tree order, from the executable's start toward the measurement locations.
(DSO|LinkedObject)[s]	Produces a summary report by linked object.
FullStack[s]	Causes the report to include the full call stack for each measurement location when added to either 'CallTree' or 'TraceBack'. Redundant call stack frames are suppressed by default if this option isn't specified.
Function[s]	Produces a summary report by function. This is the default.
Loop[s]	Produces a summary report by loop.
Statement[s]	Produces a summary report by statement.
Summary	Causes the report to include an additional line of output at the end that summarizes the information in each column. Does not apply to 'ButterFly' or 'Trace'.
SummaryOnly	Causes the report to ONLY include the line of output generated by 'Summary'.
Trace	Produces a report of each individual CUDA kernel execution or data transfer, sorted in

ascending order of the event's start time.

TraceBack[s]	Produces a calling stack report presented in traceback order, from the measurement locations toward the executable's start.

Except for the '-v Trace' option, the report will be sorted in descending order of the values in the leftmost column. Multiple '-v' values can be delimited with commas. E.g. '-v Exec,Trace'.

Finally, the columns included in the report can be controlled using the '-m' option. More than one column may be specified in a comma-delimited list. And when '-m' is used, ONLY those columns specified are reported, in order they are given.

The following '-m' options are available for '-v [Exec|Xfer]':

[%][exclusive_]count[s]	Exclusive number of events
[%]inclusive_count[s]	Inclusive number of events
[%][exclusive_]time[s]	Exclusive time in the event
[%]inclusive_time[s]	Inclusive time in the event
min[imum]	Minimum time in the event
max[imum]	Maximum time in the event
avg|average	Average time in the event
stddev	Standard deviation of time in the event
ThreadMin	Minimum accumulated time for a process
ThreadMinIndex	Process ID of the 'ThreadMin' process
ThreadMax	Maximum accumulated time for a process
ThreadMaxIndex	Process ID of the 'ThreadMax process'
ThreadAverage	Average accumulated time for a process
LoadBalance	Equivalent to 'ThreadMax, ThreadMaxIndex, ThreadMin, ThreadMinIndex, ThreadAverage'.

The following '-m' options are only available for '-v [Exec|Xfer],Trace':

(start|stop)[_time]	Start or stop time for the event

The following '-m' options are only available for '-v Exec,Trace':

block	Dimensions of each block
cache	Cache preference used
dsm	Total amount (in bytes) of dynamic shared memory reserved
grid	Dimensions of the grid
lm	Total amount (in bytes) of local memory reserved
rpt	Registers required for each thread

ssm Total amount (in bytes) of static shared reserved

The following '-m' options are only available for '-v Xfer,Trace':

size Number of bytes being transferred
kind Kind of data transfer performed
src Kind of memory from which the data transfer was performed
dest Kind of memory to which the data transfer was performed
async Was the data transfer asynchronous?

The default columns used for various '-v' combinations are:

-v Exec,Trace	-m start,time,%time,grid,block
-v Xfer,Trace	-m start,time,%time,size,kind
-v (Exec|Xfer),Butterfly	-m inclusive_time,%inclusive_time
-v (Exec|Xfer)[,<all-other>]	-m time,%time,count

The '-v HWPC' view works differently in that it only displays the sampled CPU/GPU hardware performance counters as a function of time. I.e. it does not display data as a function of source code constructs. Thus only the '-v Summary' and '-v SummaryOnly' options apply.

It also interprets the positive integer added to the end of the keyword 'cuda' differently. Instead of being the maximum number of reported items it specifies the fixed sampling interval (in ms) at which the data should be resampled before display. The default value (0) is given the special meaning that the original sampling interval should be used instead.

Examples:

expView cuda
expView -v Xfer,Fullstack cuda10 -m min,max,count
expView -v HWPC,Summary cuda33

See also:

expView

Here are some CLI views of the output from the osscuda experiment. These views show results of a cuda experiment on the CUDA application GEMM on the Pleiades SGI platform at NASA.

```
pfe27-433>openss -cli -f GEMM-cuda-4.openss
openss>>[openss]: The restored experiment identifier is:  -x 1
openss>>expview

Exclusive      % of  Exclusive  Function (defining location)
Time (ms)     Total     Count
```

```
        Exclusive
           Time
14.810702  52.042113       300  void RunTest<float>(std::string, ResultDatabase&, OptionParser&) (GEMM: GEMM.cpp,19)
13.648369  47.957887       300  void RunTest<double>(std::string, ResultDatabase&, OptionParser&) (GEMM: GEMM.cpp,19)
openss>>expstatus

Experiment definition
{ # ExpId is 1, Status is Terminated, Saved database is GEMM-cuda-4.openss
   Performance data spans 0.443760 ms  from 2016/08/24 10:01:03 to 2016/08/24 10:01:03
(none)
 Executables Involved:
  (none)
 Currently Specified Components:
  -h maia29 -p 43727 -t 0 -r 0
  -h maia30 -p 27136 -t 0 -r 1
  -h maia31 -p 80595 -t 0 -r 2
 Previously Used Data Collectors:
  cuda
 Metrics:
  cuda::count_exclusive_details
  cuda::exec_exclusive_details
  cuda::exec_inclusive_details
  cuda::exec_time
  cuda::xfer_exclusive_details
  cuda::xfer_inclusive_details
  cuda::xfer_time
 Parameter Values:
 Available Views:
  cuda
}
```

```
openss>>expview -vExec

Exclusive      % of  Exclusive  Function (defining location)
Time (ms)     Total     Count
        Exclusive
           Time
14.810702  52.042113       300  void RunTest<float>(std::string, ResultDatabase&, OptionParser&) (GEMM:
GEMM.cpp,19)
13.648369  47.957887       300  void RunTest<double>(std::string, ResultDatabase&, OptionParser&) (GEMM:
GEMM.cpp,19)
openss>>expview -vXfer

Exclusive      % of  Exclusive  Function (defining location)
Time (ms)     Total     Count
        Exclusive
           Time
 1.774178  75.232917        69  void RunTest<float>(std::string, ResultDatabase&, OptionParser&) (GEMM:
GEMM.cpp,19)
 0.584069  24.767083        69  void RunTest<double>(std::string, ResultDatabase&, OptionParser&) (GEMM:
GEMM.cpp,19)
openss>>expview -v trace, Xfer
  Start Time (d:h:m:s)        Exclusive      % of        Size     Kind Call Stack Function (defining location)
                                Time (ms)     Total
                                             Exclusive
                                             Time
2016/08/24 10:01:03.845   0.001217   0.051606    112  HostToDevice >>void RunTest<float>(std::string,
ResultDatabase&, OptionParser&) (GEMM: GEMM.cpp,19)
2016/08/24 10:01:03.850   0.027392   1.161541  262144  HostToDevice >>void RunTest<float>(std::string,
ResultDatabase&, OptionParser&) (GEMM: GEMM.cpp,19)
2016/08/24 10:01:03.850   0.027553   1.168368  262144  HostToDevice >>void RunTest<float>(std::string,
ResultDatabase&, OptionParser&) (GEMM: GEMM.cpp,19)
2016/08/24 10:01:03.851   0.001217   0.051606    112  HostToDevice >>void RunTest<float>(std::string,
ResultDatabase&, OptionParser&) (GEMM: GEMM.cpp,19)
2016/08/24 10:01:03.851   0.027425   1.162940  262144  DeviceToHost >>void RunTest<float>(std::string,
ResultDatabase&, OptionParser&) (GEMM: GEMM.cpp,19)
2016/08/24 10:01:03.852   0.026721   1.133087  262144  DeviceToHost >>void RunTest<float>(std::string,
ResultDatabase&, OptionParser&) (GEMM: GEMM.cpp,19)
```

```
2016/08/24 10:01:03.852   0.026753   1.134444  262144  DeviceToHost >>void RunTest<float>(std::string,
ResultDatabase&, OptionParser&) (GEMM: GEMM.cpp,19)
……



openss>>expview -v trace,Exec

  Start Time (d:h:m:s)       Exclusive     % of      Grid     Block    Call Stack Function (defining location)
                           Time (ms)    Total     Dims    Dims
                                        Exclusive
                                        Time
2016/08/24 10:01:03.851   0.055585   0.195316  4,4,1  16,16,1 >>void RunTest<float>(std::string, ResultDatabase&,
OptionParser&) (GEMM: GEMM.cpp,19)
2016/08/24 10:01:03.851   0.048705   0.171141  4,4,1  16,16,1 >>void RunTest<float>(std::string, ResultDatabase&,
OptionParser&) (GEMM: GEMM.cpp,19)
2016/08/24 10:01:03.851   0.049761   0.174851  4,4,1  16,16,1 >>void RunTest<float>(std::string, ResultDatabase&,
OptionParser&) (GEMM: GEMM.cpp,19)
2016/08/24 10:01:03.851   0.051617   0.181373  4,4,1  16,16,1 >>void RunTest<float>(std::string, ResultDatabase&,
OptionParser&) (GEMM: GEMM.cpp,19)
2016/08/24 10:01:03.851   0.051648   0.181482  4,4,1  16,16,1 >>void RunTest<float>(std::string, ResultDatabase&,
OptionParser&) (GEMM: GEMM.cpp,19)
2016/08/24 10:01:03.851   0.050817   0.178562  4,4,1  16,16,1 >>void RunTest<float>(std::string, ResultDatabase&,
OptionParser&) (GEMM: GEMM.cpp,19)
2016/08/24 10:01:03.851   0.046496   0.163378  4,4,1  16,16,1 >>void RunTest<float>(std::string, ResultDatabase&,
OptionParser&) (GEMM: GEMM.cpp,19)
2016/08/24 10:01:03.851   0.048193   0.169341  4,4,1  16,16,1 >>void RunTest<float>(std::string, ResultDatabase&,
OptionParser&) (GEMM: GEMM.cpp,19)
2016/08/24 10:01:03.852   0.049633   0.174401  4,4,1  16,16,1 >>void RunTest<float>(std::string, ResultDatabase&,
OptionParser&) (GEMM: GEMM.cpp,19)
….
openss>>expview -vfullstack

Exclusive      % of      Exclusive  Call Stack Function (defining location)
Time (ms)      Total     Count
               Exclusive
               Time
                         main (GEMM: main.cpp,135)
                           > @ 130 in RunBenchmark(ResultDatabase&, OptionParser&) (GEMM: GEMM.cpp,122)
11.818358  41.527561      240  >> @ 240 in void RunTest<float>(std::string, ResultDatabase&, OptionParser&)
(GEMM: GEMM.cpp,19)
                          main (GEMM: main.cpp,135)
                            > @ 137 in RunBenchmark(ResultDatabase&, OptionParser&) (GEMM: GEMM.cpp,122)
10.894840  38.282486      240  >> @ 240 in void RunTest<double>(std::string, ResultDatabase&, OptionParser&)
(GEMM: GEMM.cpp,19)
                         main (GEMM: main.cpp,135)
                           > @ 130 in RunBenchmark(ResultDatabase&, OptionParser&) (GEMM: GEMM.cpp,122)
 2.992344  10.514553      60  >> @ 231 in void RunTest<float>(std::string, ResultDatabase&, OptionParser&) (GEMM:
GEMM.cpp,19)
                         main (GEMM: main.cpp,135)
                          > @ 137 in RunBenchmark(ResultDatabase&, OptionParser&) (GEMM: GEMM.cpp,122)
 2.753529   9.675400      60  >> @ 231 in void RunTest<double>(std::string, ResultDatabase&, OptionParser&)
(GEMM: GEMM.cpp,19)
```

10 Memory Analysis Techniques

This O|SS version supports tracing memory allocation and deallocation function calls in user applications. The current functionality consists of these items:

- Timeline of events that set a new high-water mark.
- List of event allocations (with calling context) to leaks.
- Overview of all unique callpaths to traced memory calls that provides max and min allocation and count of calls on this path.

The mem experiment supports sequential, mpi and threaded applications. There is no instrumentation needed in application. The mem experiment traces the following system calls:

- malloc
- calloc
- realloc
- free
- memalign and posix_memalign

10.1 Memory Analysis Tracing (mem) experiment performance data gathering (ossmem)

To run the memory analysis experiment, use the **ossmem** convenience script and specify the application as an argument. If there are no arguments to the application then no quotes are necessary, but they are placed here for consistency. Using the sweep3d application as an example, here the ossmem script will apply the memory analysis experiment by running the sweep3d application with the O|SS memory trace collector, gather the data and will create an O|SS database file with the results of the experiment. Viewing of the performance information can be done with the GUI or CLI.

```
# Sequential example:
ossmem "./lulesh2.0"
# MPI example:
ossmem "mpirun –np 64 ./sweep3d.mpi"
```

10.2 Memory Analysis Tracing (mem) experiment performance data viewing with CLI

To launch the CLI on any experiment, use "openss –cli –f <database name>".
The following table describes the fields in the memory experiment default CLI view.

Column Name	Column Definition
Exclusive Mem Call Time	Aggregated total exclusive time spent in the memory function corresponding to this row of data.
% of Total Time	Percentage of exclusive time relative to the total time spent in the memory function

Column Name	Column Definition
	corresponding to this row of data.
Number of Calls	Total number of calls to the memory function corresponding to this row of data.
Min Request Count	The number of times minimum bytes allocated or freed occurred during this experiment.
Min Requested Bytes	The minimum number of bytes that were allocated or freed by the corresponding memory function.
Max Request Count	The number of times maximum bytes allocated or freed occurred during this experiment.
Max Requested Bytes	The maximum number of bytes that were allocated or freed by the corresponding memory function.
Total Requested Bytes	The total number of bytes allocated by the corresponding function. Note: this does not subtract the bytes freed. This only totals the allocation function requested bytes.

Important command line interface (CLI) views are listed below:

- **expview -vunique**
  - Show times, call counts per path, min,max bytes allocation, total allocation to all unique paths to memory calls that the mem collector saw
- **expview -vleaked**
  - Show function view of allocations that were not released while the mem collector was active
- **expview -vtrace,leaked**
  - Will show a timeline of any allocation calls that were not released
- **expview -vfullstack,leaked**
  - Display a full callpath to each unique leaked allocation
- **expview -v trace,highwater**
  - Is a timeline of mem calls that set a new high-water
  - The last entry is the allocation call that the set the high-water for the complete run
  - Investigate the last calls in the timeline and look at allocations that have the largest allocation size (size1,size2,etc) if your application is consuming lots of system ram

❖ Here we show a default view of the output from the ossmem experiment run of matmul on a small cluster. This view shows the last 8 allocation events that set the high water mark.

```
openss>>expview -vtrace,highwater
  Start Time(d:h:m:s)  Event    Size  Size  Ptr    Return Value      New  Call Stack Function (defining
location)
                Ids    Arg1  Arg2  Arg            Highwater
```

```
*** trimmed all but the last 8 events of 61 ****
2016/11/10 09:56:50.824 11877:0    2080    0       0x7760e0 19758988 >>>>>>>__GI__libc_malloc
(libc-2.18.so)
2016/11/10 09:56:50.826 11877:0 1728000    0       0x11783d0 21484908 >>>>__GI__libc_malloc
(libc-2.18.so)
2016/11/10 09:56:50.827 11877:0 1728000    0       0x131e1e0 23212908 >>>>__GI__libc_malloc
(libc-2.18.so)
2016/11/10 09:56:50.827 11877:0 1728000    0       0x14c3ff0 24940908 >>>>__GI__libc_malloc
(libc-2.18.so)
2016/11/10 09:56:50.827 11877:0    2080    0       0x776a90 24942988 >>>>>>>__GI__libc_malloc
(libc-2.18.so)
2016/11/10 09:56:50.919 11877:0 1728000    0       0x1654030 25286604 >>>>__GI__libc_malloc
(libc-2.18.so)
2016/11/10 09:56:50.919 11877:0 1728000    0       0x17f9e40 27014604 >>>>__GI__libc_malloc
(libc-2.18.so)
2016/11/10 09:56:50.919 11877:0    2080    0       0xabc6a0 27016684 >>>>>>>__GI__libc_malloc
(libc-2.18.so)
```

The next view shows the default view of all unique memory calls seen while the **mem** collector was active. This is an overview of the memory activity. The default is display is aggregated across all processes and threads. Can view specific processes or threads.

For all memory calls the following are displayed:

- The exclusive time and percent of exclusive time
- The number of times this memory function was called.
- The traced memory function name.

For allocation calls (e.g. malloc) the follow:

- The maximum and minimum allocation size seen.
- The number of times the that maximum or minimum was seen are displayed.
- The total allocation size of all allocations.

```
openss>>expview -vunique
Exclusive    % of      Number     Min      Min        Max      Max         Total      Function (defining
location)
  (ms)      Total       of      Request  Requested  Request  Requested   Bytes
            Time       Calls    Count    Bytes      Count    Bytes       Requested

 0.024847 89.028629   1546       1        192        6        4096        6316416   __GI__libc_malloc
(libc-2.18.so)
 0.002371  8.495467   5                                                            __GI__libc_free (libc-
2.18.so)
 0.000369  1.322154   1          1        40         1        40          40          __realloc (libc-2.18.so)
 0.000322  1.153750   3          1        368        1        368         1104        __calloc (libc-2.18.so)
```

NOTE: Number of Calls means the number of unique paths to the memory function call. To see the paths use the CLI command: expview –vunique,fullstack

In this example the sequential OpenMP version of lulesh was run under ossmem. The initial run detected 69 potential leaks of memory. Examining the calltrees using the cli command "**expview -vfullstack,leaked -mtot_bytes**"

revealed that allocations from the Domain::Domain constructor where not later released in the Domain::~Domain destructor. After adding appropriate delete's in the destructor and rerunning ossmem, we observed a resolution of the leaks detected in the Domain class. The remaining leaks where minor and from system libraries.

Using the exprestore command to load in the initial database and the database from the second run, we can use the expcompare cli command to see the improvements.

Below, database -x1 shows the initial run and -x2 shows the results from the run with the changes to address the leaks detected in the Domain class.
.

```
openss>>exprestore -f lulesh-mem-initial.openss
openss>>exprestore -f lulesh-mem-improved.openss
openss>>expcompare -vleaked -mtot_bytes -mcalls -x1 -x2

  -x 1,       -x 1,    -x 2,       -x 2,    Function (defining location)
  Total    Number  Total      Number
  Bytes       of       Bytes        of
Requested  Calls  Requested   Calls
10599396     69     3332          8    __GI__libc_malloc (libc-2.17.so)
        72      1       72          1    __realloc (libc-2.17.so)
```

10.2.1 Additional CLI Information

expview -v summary -mcounts is important to see before issuing queries since the current mem collector records every event it sees and there can be many.

```
openss>>expstatus
{ # ExpId is 1, Status is Terminated, Saved database is mpiperf-mem-3.openss
   Performance data spans 13.561511 seconds  from 2016/06/14 19:27:27 to 2016/06/14 19:27:40
 Executables Involved:
            mpiperf
 Currently Specified Components:
   -h localhost.localdomain -p 21952 -t 0 -r 0 (mpiperf)
   -h localhost.localdomain -p 21953 -t 0 -r 1 (mpiperf)

openss>>[openss]: The restored experiment identifier is:  -x 1
openss>>expview -mcounts -vsummary

Number  Function (defining location)
   of
 Calls
400002  malloc (libc-2.18.so)
400000  __cfree (libc-2.18.so)
800002  Report Summary
```

As one can see, 800000 events in just 13 seconds across two ranks.
An expview -v trace will take a lot of time just to display.

For malloc, you can get the unique callpaths to malloc's for example using this. Here we sort on the allocation size requested by malloc and show times down the unique callstack for all ranks (2).

Add -r to choose a specific rank.

This query is showing 400000 allocations of 16 bytes on one particular path.

```
openss>>expview -v fullstack -fmalloc -msize1,counts

Size  Number  Call Stack Function (defining location)
 Arg     of
    Calls
         _start (mpiperf)
         > @ 562 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
         >>__libc_start_main (libc-2.18.so)
         >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
         >>>> @ 37 in main (mpiperf: mpiperf.c,22)
         >>>>> @ 627 in mp_parse_cmd (mpiperf: mpiperf.c,57)
         >>>>>> @ 825 in mp_sendrecv (mpiperf: mpiperf.c,816)
         >>>>>>>PMPI_Sendrecv (libmpi.so.1.6.0)
         >>>>>>>>mca_pml_ob1_send (libmpi.so.1.6.0)
         >>>>>>>>>opal_progress (libopen-pal.so.6.2.1)
           >>>>>>>>>>mca_btl_vader_component_progress (libmpi.so.1.6.0)
           >>>>>>>>>>>mca_pml_ob1_recv_frag_callback_rndv (libmpi.so.1.6.0)
           >>>>>>>>>>>>match_one (libmpi.so.1.6.0)
           >>>>>>>>>>>>>append_frag_to_list (libmpi.so.1.6.0)
           >>>>>>>>>>>>>>mca_allocator_bucket_alloc (libmpi.so.1.6.0)
4112       1 >>>>>>>>>>>>>>>malloc (libc-2.18.so)
         _start (mpiperf)
         > @ 562 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
         >>__libc_start_main (libc-2.18.so)
         >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
         >>>> @ 37 in main (mpiperf: mpiperf.c,22)
         >>>>> @ 627 in mp_parse_cmd (mpiperf: mpiperf.c,57)
         >>>>>> @ 825 in mp_sendrecv (mpiperf: mpiperf.c,816)
         >>>>>>>PMPI_Sendrecv (libmpi.so.1.6.0)
         >>>>>>>>mca_pml_ob1_send (libmpi.so.1.6.0)
         >>>>>>>>>opal_progress (libopen-pal.so.6.2.1)
        >>>>>>>>>>mca_btl_vader_component_progress (libmpi.so.1.6.0)
         >>>>>>>>>>>mca_pml_ob1_recv_frag_callback_rndv (libmpi.so.1.6.0)
        >>>>>>>>>>>>match_one (libmpi.so.1.6.0)
        >>>>>>>>>>>>>append_frag_to_list (libmpi.so.1.6.0)
        >>>>>>>>>>>>>>mca_allocator_bucket_alloc (libmpi.so.1.6.0)
4112       1 >>>>>>>>>>>>>>>malloc (libc-2.18.so)
         _start (mpiperf)
         > @ 562 in __libc_start_main (libmonitor.so.0.0.0: main.c,541)
         >>__libc_start_main (libc-2.18.so)
         >>> @ 517 in monitor_main (libmonitor.so.0.0.0: main.c,492)
         >>>> @ 37 in main (mpiperf: mpiperf.c,22)
```

```
        >>>>> @ 314 in mp_parse_cmd (mpiperf: mpiperf.c,57)
        >>>>>> @ 692 in mp_allreduce (mpiperf: mpiperf.c,686)
        >>>>>>>MPI_Allreduce (libmpi.so.1.6.0)
        >>>>>>>>ompi_coll_tuned_allreduce_intra_recursivedoubling (libmpi.so.1.6.0)
 16  400000  >>>>>>>>>malloc (libc-2.18.so)
```

Here is where mpiperf.c is calling MPI_Allreduce which is doing all the mallocs.

```
openss>>!sed -n 680,700p mpiperf.c
openss>>    stop = MPI_Wtime();

   return stop - start;
}

double mp_allreduce(int msg_size, int steps, int rank, int size)
{
   double start, stop;
   int i;

   MPI_Barrier(MPI_COMM_WORLD);
   start = MPI_Wtime();
   for (i=0; i < steps; i++) {
   MPI_Allreduce(sendbuf, recvbuf, msg_size, mp_data_type, mp_op, MPI_COMM_WORLD);
   }
   stop = MPI_Wtime();

   return stop - start;
}

double mp_alltoall(int msg_size, int steps, int rank, int size)
```

These are additional important -m options, as these are per call.
See the man pages of these calls for the details on the return values and arguments.

void *malloc(size_t size);
-m retval shows the address to the returned memory
-m size1 shows the amount of the allocation request.

void free(void *ptr);
-m ptr shows the address of the free request. matching this to addresses allocated in any
of the malloc calls will show if an allocation is free'd or not. not done in our views. one would have to dump a complete -v trace to a text file and matchup allocations and frees.

void *calloc(size_t nmemb, size_t size);
-m retval shows the address to the returned memory
-m size1 = nmemb
-m size2 = size

void *realloc(void *ptr, size_t size);

-m retval shows the address to the returned memory
-m ptr is the ptr to the existing mem location
-m size1 is the realloc request size

int posix_memalign(void **memptr, size_t alignment, size_t size);
-m ptr is the pointer to the memory address
-m size1 os alignment
-m size2 is size
-m retval is the address that would later be passed to free

void *memalign(size_t alignment, size_t size);
-m retval shows the address to the returned memory
-m size1 is alignment
-m size2 is size

Any call that has a size parameter can use
-m max_bytescount
-m min_bytescount
-m max_bytes
-m min_bytes
-m tot_bytes

This will show total allocations done per unique callpath, add -mcounts to see number of times traversed:
expview -v fullstack -mtot_bytes

This will sort on largest to smallest MAX allocations done per unique callpath, add -mcounts to see number of times traversed:
expview -v fullstack -mmax_bytes

This will sort on largest to smallest MIN allocations done per unique callpath, add -mcounts to see number of times traversed:
expview -v fullstack -mmin_bytes

In some cases, the MAX and MIN will match if they are equal for any particular allocation path.

10.3 Memory Analysis Tracing (mem) experiment performance data viewing with GUI

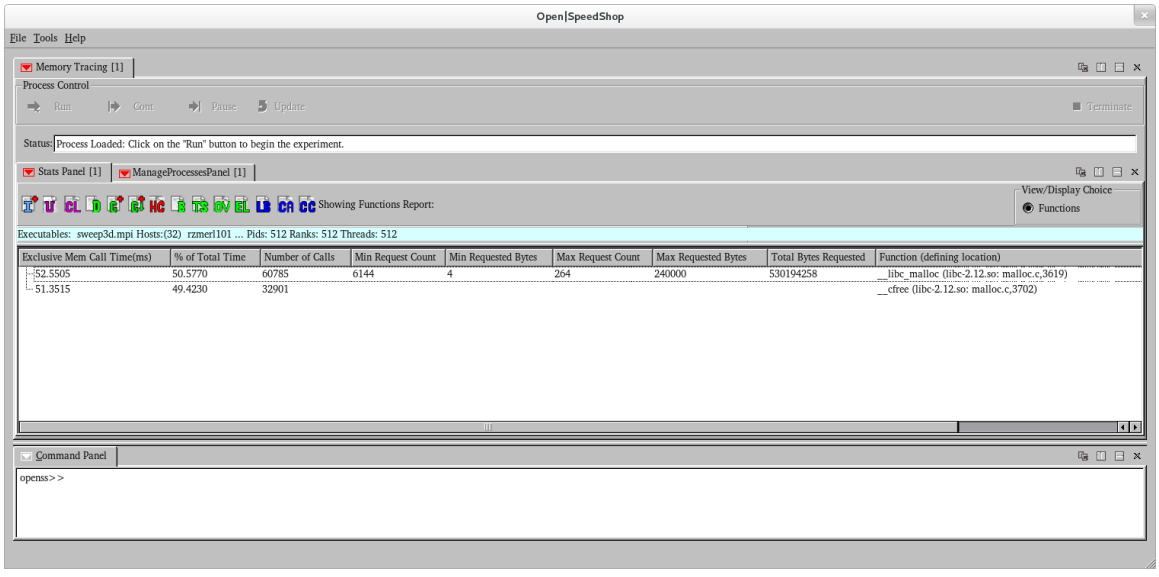
To launch the GUI on any experiment, use “openss –f <database name>“.

The first GUI view show below is the default view for the mem experiment. It shows the memory functions that were called in the application, how many times they were called, the time spent in each of the memory functions, and the percentage of

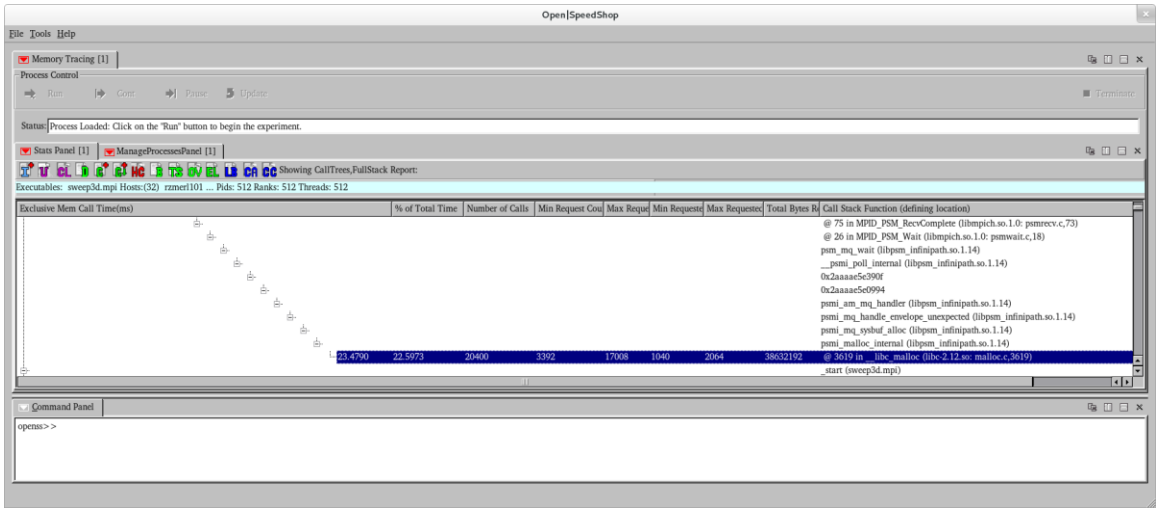
the overall memory function time was spent in each of the memory functions. This table identifies what each of the columns represent in the default GUI view for the mem experiment.

Column Name	Column Definition
Exclusive Mem Call Time	Aggregated total exclusive time spent in the memory function corresponding to this row of data.
% of Total Time	Percentage of exclusive time relative to the total time spent in the memory function corresponding to this row of data.
Number of Calls	Total number of calls to the memory function corresponding to this row of data.
Min Request Count	The number of times minimum bytes allocated or freed occurred during this experiment.
Min Requested Bytes	The minimum number of bytes that were allocated or freed by the corresponding memory function.
Max Request Count	The number of times maximum bytes allocated or freed occurred during this experiment.
Max Requested Bytes	The maximum number of bytes that were allocated or freed by the corresponding memory function.
Total Requested Bytes	The total number of bytes allocated by the corresponding function. Note: this does not subtract the bytes freed. This only totals the allocation function requested bytes.

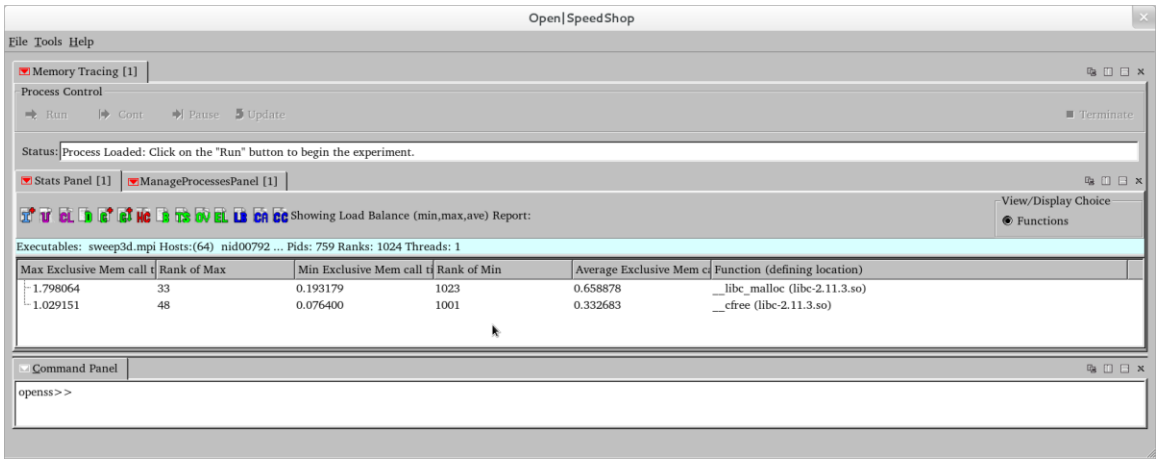
The paths to each memory, through the source, are available through the call path views.



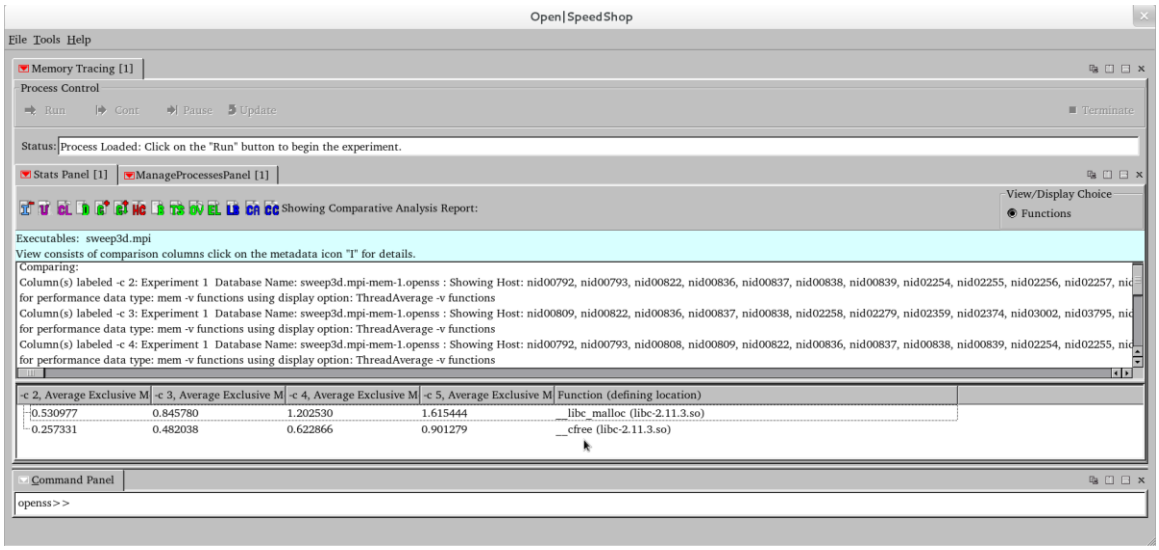
In this (C+ icon) call path view we see the call paths to the memory functions called in this application.



In the view below, one has chosen the “LB” icon and generated the load balance view. This view shows the min, max, and average time across all the ranks in the application. The ranks of the min and max time values are also shown. If there is a significant difference between the min, max, and average time, there may be load imbalance. To identify the ranks, threads, or processes that are acting out of balance, use the cluster analysis feature activated by clicking on the “CA” icon.



In this view, generated by clicking on the “CA” icon, we see that O|SS has determined that there are four unique groups where the aggregate time for the groups differs enough to report this to the user. The columns in the Stats Panel display show the times that are reflective of each of the ranks in the group. The information (I+) icon can be used to view which ranks, etc. are included in each of the cluster groups.



11 Advanced Analysis Techniques

Analyzing the results of a single performance experiment can be useful for debugging and tuning your code. But comparing the results of different experiments can show you how the performance of an application has changed. This is useful if you want to track how the performance varies for each new version of an application, or understanding how a different compiler or compiler options can affect the performance of your application. This also allows you to do scalability tests to see how the performance of your application scales with the number of processors. It's also helpful just to see the progress you have made while tuning your code.

O|SS has options to allow you to compare performance data. You can use the Custom Compare Panel (CC icon) in the GUI or the osscompare convenience script.

```
> osscompare "db1.openss, db2.openss,..." [options]
```

This will produce a side-by-side comparison listing, you can compare up to 8 databases at once. You can see the osscompare man page for more details. Below is an example of comparing two different pcsamp experiments on the smg2000 application.

```
osscompare "smg2000-pcsamp.openss,smg2000-pcsamp-1.openss"

[openss]: Legend: -c 2 represents smg2000-pcsamp.openss
[openss]: Legend: -c 4 represents smg2000---pcsamp---1.openss
-c 2, Exclusive CPU          -c 4, Exclusive CPU      Function (defining location)
time in seconds.             time in seconds.
  3.870000000                3.630000000        hypre_SMGResidual (smg2000:smg_residual.c,152)
  2.610000000                2.860000000        hypre_CyclicReduction (smg2000:cyclic_reduc;on.c,757)
  2.030000000                0.150000000        opal_progress (libopen-pal.so.0.0.0)
  1.330000000                0.100000000        mca_btl_sm_component_progress (libmpi.so.0.0.2)
```

```
0.280000000     0.210000000     hypre_SemiInterp (smg2000: semi_interp.c,126)
0.280000000     0.040000000     mca_pml_ob1_progress (libmpi.so.0.0.2)
```

11.1 Comparison Script Argument Description

The O|SS comparison script accepts a number of arguments. This section describes the acceptable options for those individual arguments. For a quick overview see section *14.4 osscompare: Compare Database Files*. As described above the osscompare script accepts at least two and up to eight comma separated database file names, enclosed in quotes as the mandatory argument. By default, the compared metric is the primary metric produced by the experiment. For most experiments, the metric is exclusive time, however the hardware counter experiments use the count of the number of hardware counter overflows as the metric to be compared. These are the default or mandatory arguments to osscompare. The following sections describe the arguments for osscompare in more detail.

11.1.1 osscompare metric argument

The osscompare metric argument specifies the performance information type that O|SS will use to compare against when looking at each database file in the compare database file list. To find the metric specifications that are legal and produce comparison outputs, one can open one of the database files with the O|SS command line interface (CLI), and list the available metrics.

```
openss -cli -f smg2000-pcsamp.openss
  openss>>list -v metrics
  pcsamp::percent
  pcsamp::threadAverage
  pcsamp::threadMax
  pcsamp::threadMin
  pcsamp::time
```

You can use the output of the list metrics command as an argument to the osscompare command as shown in the examples below.

```
osscompare "smg2000-pcsamp.openss,smg2000-pcsamp-1.openss"
osscompare "smg2000-pcsamp.openss,smg2000-pcsamp-1.openss" percent
osscompare "smg2000-pcsamp.openss,smg2000-pcsamp-1.openss" threadMin
osscompare "smg2000-pcsamp.openss,smg2000-pcsamp-1.openss" threadMax
```

Some exceptions do apply. For example, some experiments such as usertime and hwctime have “details” type metrics output by the list metrics CLI command (list –v metrics). These will not work as a metric argument to osscompare.

For the hardware counter experiments: hwc and hwctime, you can use the actual PAPI event name in addition to the metric names output from the list metric command. The example database file was generated using the PAPI_TOT_CYC event.

```
openss -cli -f smg2000-hwc.openss
openss>>[openss]: The restored experiment identifier is:  -x 1
openss>>list -v metrics
hwc::overflows
hwc::percent
hwc::threadAverage
hwc::threadMax
hwc::threadMin
```

Here, we show a couple osscompare examples where “hwc::overflows” can be used interchangeably with PAPI_TOT_CYC.

```
osscompare "smg2000-hwc.openss,smg2000-hwc-1.openss" hwc::overflows
osscompare "smg2000-hwc.openss,smg2000-hwc-1.openss" PAPI_TOT_CYC
```

Note that for compares involving hwcsamp metric based databases, to compare all of the existing hardware counters from each experiment, use the “allEvents” metric in the osscompare command. That will compare all the events in each of the databases and will ignore the program counter sampling data from each of the databases. The form of the osscompare command to compare all the hardware counter events is as follows:

```
osscompare "smg2000-hwcsamp.openss,smg2000-hwcsamp-1.openss" allEvents
```

11.1.2 osscompare rows of output argument

osscompare allows the user to specify how many lines of the comparison output to be output. The argument is optional and

"**rows=**nn" is defined as follows:
"nn" - Number of rows/lines of performance data output.

In this example, only ten (10) lines of comparison will be shown when the osscompare command is executed. It will be the most interesting, or top, ten lines.

```
osscompare "smg2000-hwc.openss,smg2000-hwc-1.openss" hwc::overflows rows=10
```

11.1.3 osscompare output name argument.

osscompare allows the user to specify the name to be used when writing out the comparison output files. The argument is optional and

"**oname**=<output file name>" is defined as follows:
"output file name" - Name given to the output files created for the comparison.

This argument is valid when the environment variable OPENSS_CREATE_CSV is set to 1. In this example, the comparison files created when the osscompare command is executed will be named smg_hwc_cmp.csv and/or smg_hwc_cmp.txt.

```
osscompare "smg2000-pcsamp.openss,smg2000-pcsamp-1.openss" oname=mar2015_pcsamp_cmp
```

This example will generate comparison files named using the specified oname specification.

```
8 -rw-rw-r--. 1 jeg jeg   4475 Mar 11 15:53 mar2015_pcsamp_cmp.compare.csv
8 -rw-rw-r--. 1 jeg jeg   4841 Mar 11 15:53 mar2015_pcsamp_cmp.compare.txt
```

11.1.4 osscompare view type or granularity argument.

osscompare allows an optional view type argument. It represents the granularity of the view. O|SS allows for viewing performance data at three levels: linked object level, function level, and at the statement level. osscompare will produce output at one of those levels based on the view type argument where:

```
"viewtype=<functions | statements | linkedobjects >" is defined as follows:
        "functions"        - View type granularity is per function
        "statements"       - View type granularity is per statement
        "linkedobjects"  - View type granularity is per library (linked object)
```

This example will produce a side-by-side comparison for the statement level, not the default function level. So, this example will compare statement performance values in each of the two databases and produce a side-by-side comparison showing how each statement in the application differed from the two experiments.

```
osscompare "smg2000-pcsamp.openss,smg2000-pcsamp-1.openss" viewtype=statements
```

12 Open|SpeedShop User Interfaces

Throughout this manual we have been using the Open|SpeedShop (O|SS) GUI, we would encourage you to play around with the interface to become familiar with it. The GUI lets you peel-off and rearrange any panel. There are also context sensitive menus so you can right click on any location to access a different view or to activate additional panels.

If you prefer not to use the GUI there are three other options that all have equal functionality. First there is the command line interface that we have also seen throughout this manual, which you can launch with the –cli option:

```
> openss -cli
```

There is also the immediate command (batch) interface. This uses the –batch flag:

```
> openss –batch < openss_cmd_file
> openss –batch –f <exe> <experiment>
```

Lastly there is a python scripting API, so you can launch O|SS commands within a python script.

```
> python openss_python_script_file.py
```

12.1 Command Line Interface Basics

The CLI offers an interactive command line interface with processing like gdb or dbx. There are several interactive commands that allow you to create experiments, provide you with process/thread control or enable you to view experiment results. You can find the full CLI documentation at http://www.openspeedshop.org/doc/cli_doc/ but here we will briefly cover some important points. Here is a quick overview of some commands (those marked with a * are only available for the online version):

Experiment Creation • expcreate • expattach*	**Result Presentation** • expview • opengui
Experiment Control • expgo • expwait* • expdisable* • expenable*	**Misc. Commands** • help • list • log • record • playback • history • quit
Experiment Storage • expsave • exprestore	

The following is a simple example to create, run and view data from an experiment using the CLI.

> openss –cli	Open the CLI.
openss>> expcreate –f "mutatee 2000" pcsamp	Create an experiment using pcsamp with this application.
openss>> expgo	Run the experiment and create the database
openss>> expview	Display the default view of the performance data.

You can also get alternative views of the performance data within the CLI. The following is a list of some options to change the way the information is displayed.

help or help commands	Display CLI help text
expview	Show the default view for experiment
expview -v statements	Show time-consuming statements
expview -v loops	Show time-consuming loops
expview -v linkedobjects	Show time spent in libraries
expview -v fullstack	See all unique call paths in the application.
expview -m loadbalance	See load balance across all the ranks/threads/processes in the experiment.
expview –r <rank_num>	See data for specific rank(s)

expcompare –r 1 –r 2 –m time	Compare rank 1 to rank 2 for metric equal to "time". Other metrics are allowed. This is a usage example.
list –v metrics	See the list of optional performance data metrics.
list –v src	See the list of source files associated with experiment.
list –v obj	See the list of object files associated with experiment.
list –v ranks	See the list of ranks associated with experiment.
list –v hosts	See machine host names associated with experiment.
expview –m <metric>	See performance data for the metric specified.
expview –v fullstack <experiment type> <number>	See <number> of call paths from the list of expensive call paths.
expview –v fullstack usertime2	Shows the top two call paths in execution time.
expview <experiment-name><number>	Shows <number> of the functions from the list of the top time-consuming functions.
expview pcsamp2	Shows the two functions taking the most time.
expview –v statements <experiment-name><number>	Show <number> of the statements from the list of the top time-consuming statements
expview -Fcsv	Show the view in comma separated list format (csv)

Remember if you want the GUI at any time just issue the command **opengui** in the CLI.

12.1.2 CLI Metric Expressions and Derived Types

O|SS has the capability to create derived metric from the gathered metrics by using the metric expression math functionality in the command line interface (CLI). One can access the overview from the CLI by typing this help CLI command.

```
openss>>help metric_expression

  *********
<metric_expression> ::=<string> ( [<constant> ||<metric_expression> ] [ ,
[<constant> ||<metric_expression> ] ]* )

A user defined expression that uses metrics to compute a special value for display in a report.

User defined expression can be added to an<expMetric_list>.
A functional notation is used to build the desired expression and the following, simple, arithmetic operations are
available:
  Function    # arguments    returns
  --------    -----------    -------
  Uminus()     1    unary minus of the argument
  Abs()        1    Absolute value of the argument
  Add()        2    summation of the arguments
  Sub()        2    difference of the arguments
  Mult()       2    product of the arguments
  Div()        2    first argument divided by second
  Mod()        2    remainder of divide operation
  Min()        2    minimum of the arguments
  Max()         2    maximum of the arguments
  A_Add()      1    sum of all the data samples specified for the view
  A_Mult()     1    product of all the data samples specified for the view
  A_Min()      1    minimum of all the data samples specified for the view
  A_Max()      1    maximum of all the data samples specified for the view
  Sqrt()       1    square root of the argument
```

```
  Stdev()      3   standard deviation calculation
  Percent()    2   percent the first argument is of the second
  Condexp()    3   "C" expression: "(first argument) ? second argument: third argument"
  Header()     2   use the first argument as a column header for the display of the second

Note:

Integer and floating constants are supported as arguments as are the metric keywords associated with the
experiment view.

Arguments to these functions can be<metric_expressions>, with the exception of the first argument of 'Header'.

The first argument of 'Header' must be a character string that is preceded with and followed by '\"'.

When the '-v summary' option is used, it is not generally possible to produce a meaningful column summary.
A summary is produced for Add(), Max(), Min(), Percent(), A_Add(), A_Max and A_Min().

Examples:

  expview hwc -m count,Header(\"percent of counts\",Percent(count,A_Add(count)) -v summary
  expview mpi -v butterfly -f MPI_Alltoallv -m time,Header("average time/count",Div(Mult(time,1000),counts))
  expview -m papi_l2_tca,papi_l2_tcm,Header(\"percent of l2_tcm/l2_tca\", Percent(papi_l2_tcm,papi_l2_tca))
```

To examine an example, we take the default view, expview command and add the capability to add the percentage that each function contributes to the total.

Add the header by using the “Header” phrase to create a header for the new data column that is being added. The “Percent” phrase to create the arithmetic expression that divides the PAPI_L1_DCM counts (count) for each function by the total number of PAPI_L1_DCM counts in the application(A_Add(count)).

```
openss>>expview  -m count,Header(\"percent of counts\",Percent(count,A_Add(count)))

 Exclusive        percent    Function (defining location)
PAPI_L1_DCM  of counts
   Counts
 342000000    52.333588  hypre_SMGResidual (smg2000: smg_residual.c,152)
 207500000    31.752104  hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
  20500000     3.136955  hypre_SemiInterp (smg2000: semi_interp.c,126)
  15000000     2.295333  hypre_SemiRestrict (smg2000: semi_restrict.c,125)
   8500000     1.300689  pack_predefined_data (libmpi.so.0.0.3)
   7000000     1.071155  unpack_predefined_data (libmpi.so.0.0.3)
```

Another example, this one based in the hwcsamp experiment view, shows the ratio between total cache accesses and total cache misses. We create a header that is defined by the Header clause.

```
openss>>expview -m papi_l2_tca,papi_l2_tcm,Header(\"percent of l2_tcm/l2_tca\", Percent(papi_l2_tcm,papi_l2_tca))

papi_l2_tca  papi_l2_tcm   percent of              Function (defining location)
                           l2_tcm/l2_tca

 289946516   109226440     37.671237  hypre_SMGResidual (smg2000: smg_residual.c,152)
 203463495    74795126     36.760956  hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
  34442810    12746112     37.006597  mca_btl_vader_check_fboxes (libmpi.so.1.4.0: btl_vader_fbox.h,108)
  25522126     8311723     32.566734  hypre_SemiInterp (smg2000: semi_interp.c,126)
```

…
…

12.1.3 CLI Automatically Generated Derived Metrics and CLI Derived Metric Names

The CLI view code has logic to match up existing PAPI hardware counters with other PAPI hardware counters, if the user specified a combination of counters that O|SS has been coded to recognize. These combinations of counters have been requested by users as combinations that would be interesting to have pre-computed and output in the CLI views.

The list of automatically generated and displayed derived metric values are discussed in the following paragraphs. A short list of the metric name that can be used in the CLI view and the hardware counters needed is displayed below:

Computational Intensity	-m intensity	PAPI_TOT_INS/PAPI_TOT_CYC
	-m l1dcmiss	PAPI_L1_DCM/PAPI_L1_TCA
	-m l2tcmiss	PAPI_L2_TCM/PAPI_L2_TCA
	-m l3tcmiss	PAPI_L3_TCM/PAPI_L3_TCA

12.1.3.1 Computational Intensity

For this derived metric, a ratio is created based on the number of total instructions (PAPI_TOT_INS) divided by the PAPI_TOT_CYC hardware counter value. This ratio gives an idea of the instruction execution computational intensity. TBD.

12.1.3.2 Level 1 Data Cache Miss Ratio

For this derived metric, a ratio is created based on the number of total level 1 cache accesses with the level 1 data cache misses. This ratio gives… TBD.

12.1.3.3 Level 2 Data Cache Miss Ratio

For this derived metric, a ratio is created based on the number of total level 2 cache accesses with the level 2 data cache misses. This ratio gives… TBD.

12.1.3.4 Level 3 Data Cache Miss Ratio

For this derived metric, a ratio is created based on the number of total level 3 cache accesses with the level 3 data cache misses. This ratio gives… TBD.

12.2 CLI Batch Scripting

If you have a known set of command, you want to issue you can create a plain text file with CLI commands. For example, we create a batch file that will create, run then view the pcsamp experiment run on the application fred.

```
# Create batch file commands
> echo expcreate –f fred pcsamp >> input.script
> echo expgo >> input.script
> echo expview pcsamp10 >> input.script
```

Now to run the batch file input.script we use the –batch option to openss.

```
> openss –batch < input.script
```

Note that currently, in this context, this interface is only supported via the online version of O|SS, so it must have been build with the OPENSS_INSTRUMENTOR=mrnet options.

12.3 Python Scripting

The O|SS python API allows users to execute the same interactive/batch commands directly through python. Users can intersperse the normal python code with commands to O|SS. Currently this interface is only supported via the online version of O|SS.

12.4 MPI_Pcontrol Support

O|SS also supports the MPI_Pcontrol function. This feature allows the user to gather performance data only for sections of their code bounded by the MPI_Pcontrol calls.

The MPI_Pcontrol must be added to the source code of the application.

MPI_Pcontrol(1) enables the gathering of performance data and MPI_Pcontrol(0) disables the gathering.

You must also set the O|SS environment variable OPENSS_ENABLE_MPI_PCONTROL to 1 in order to activate the MPI_Pcontrol call recognition, otherwise it will be ignored.

Optionally you can set the OPENSS_START_ENABLED environment variable to 1 to have performance data gathered until a MPI_Pcontrol(0) call is encountered.

If OPENSS_START_ENABLED is no set no performance data will be gathered until a MPI_Pcontrol(1) call is encountered.

Note that for OPENSS_START_ENABLED to have any effect, OPENSS_ENABLE_MPI_PCONTROL must be set.

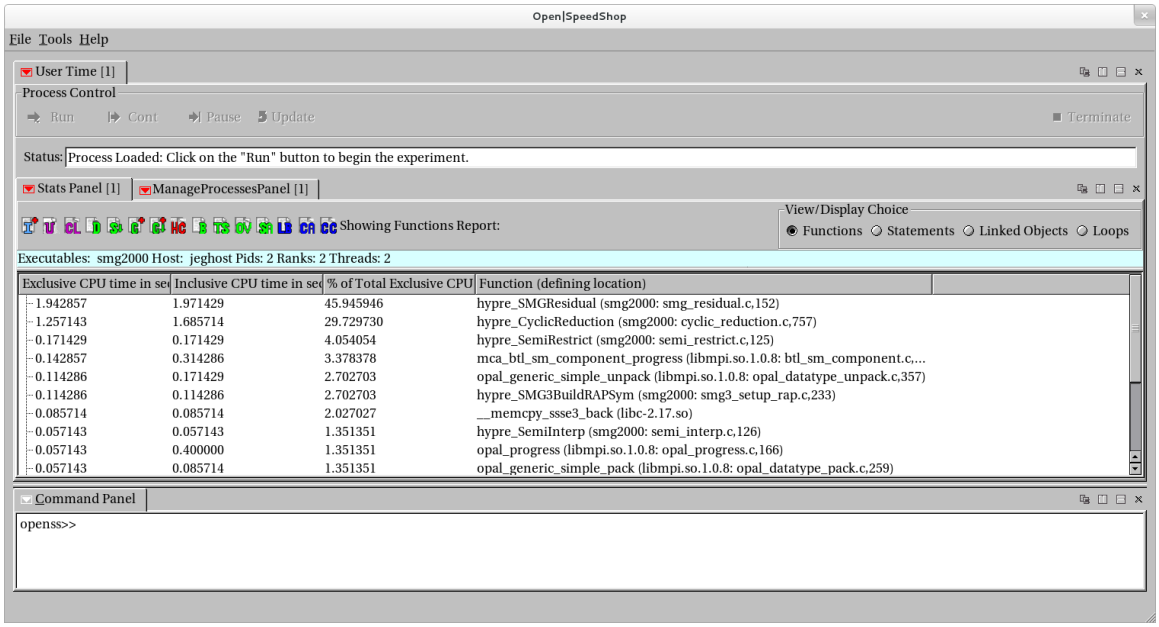
12.5 Graphical User Interface Basics

This section gives an overview of the O|SS graphical user interface focusing on the basic functionality of the GUI.

To launch the GUI on any experiment, use “openss –f <database name>”.

12.5.1 Basic Initial View – Default View

Because this example usertime experiment default view has many of the icons and features of the other O|SS experiments it is used here for illustration purposes.



12.5.1.1 Icon ToolBar

The most used items that can be found in the Stats Panel menu that is found under the Stats Panel tab are also available in the Stats Panel ToolBar. The Stats Panel Toolbar is provided as a convenience. The following is a quick overview of the toolbar options. The contents of the toolbar vary by experiment, because some options don't make sense for all experiments. The following table describes the icons and the functionality they represent.

"I"	Information	This option shows the metadata for the experiment. Information such as the experiment type, processes, ranks, threads, hosts, and other experiment specific information is displayed.
“U”	Update	This option updates the information in the Stats Panel display. This can be used to display any new data that may have come from the nodes on which the application is running.
"CL"	Clear auxiliary information	Clear auxiliary information. If the user has chosen a time segment of the performance data or a specific function to view the data for. This option clears the settings for that and allows the next view selection to show data for the entire program again.
"D"	Default View	The default view icon shows the performance results based on the view choice granularity selection.
"S, down arrow"	Statements per Function	Show the performance results related back to the source statements in the application for the selected function. Highlight a function in the Stats Panel and click on this icon.
"C, plus sign"	Call paths w/o coalescing	Show all the calling paths in this application. Duplicate paths will not be coalesced. All of the calling paths will be shown in their entirety.
"C, plus sign, down arrow"	Call paths w/o coalescing per Function	Show all the calling paths in this application for the selected function only. Highlight a function in the Stats Panel and click on this icon. Duplicate paths will not be coalesced. All of the calling paths will be shown in their entirety.
"HC"	Hot Call Path	Show the call path in the application that took the most time. This is a short cut to find the "hot" call path.
"B"	Butterfly view	Show the butterfly view, which displays the callers and callees of the selected function. Highlight a function in the Stats Panel and click on this icon. Then repeat to "drill" down into the callers and/or callees.
"TS"	Time Segment	Show a portion of the performance data results based on the time segment selected.
"OV"	Optional View	Use this dialog to select which performance metrics to be shown in the new performance data report.
“SA”	Source Annotation	Choose which metric to use in the source panel to annotate the source. Defaults are different for each experiment, but mostly: time.
"LB"	Load Balance	Show the load balance view, which displays the min, max, and average performance values for the application. Only available on threaded or multiple process applications.
"CA"	Cluster Analysis	Show the comparative analysis view, which displays the output of a cluster analysis algorithm run against the threaded or multiple process performance analysis results for the user application. The goal of this view is to find outlying threads or processes and report the groups of like performing threads, processes, or ranks.
"CC"	Custom Compare	Raise the custom comparison panel, which provides mechanisms allowing the user to create custom views of the performance analysis results. This allows the user to supplement the provided O|SS views.

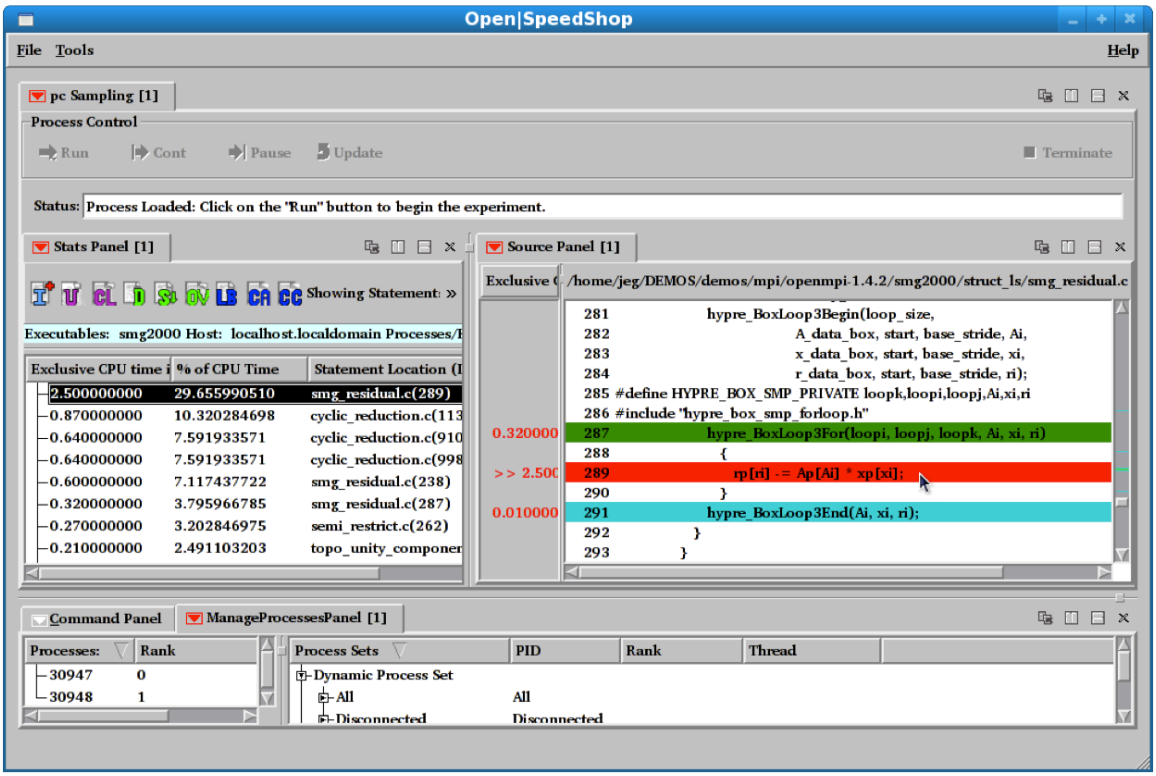
12.5.1.2 View/Display Choice Selection

The View/Display Choice set of buttons allows users to choose what granularity to use for a particular display. The normal usage scenario, is to choose a view choice

granularity and then select a view by choosing one of the icons described in the table above. The choices, as shown in the image below, are to see the performance data displayed:

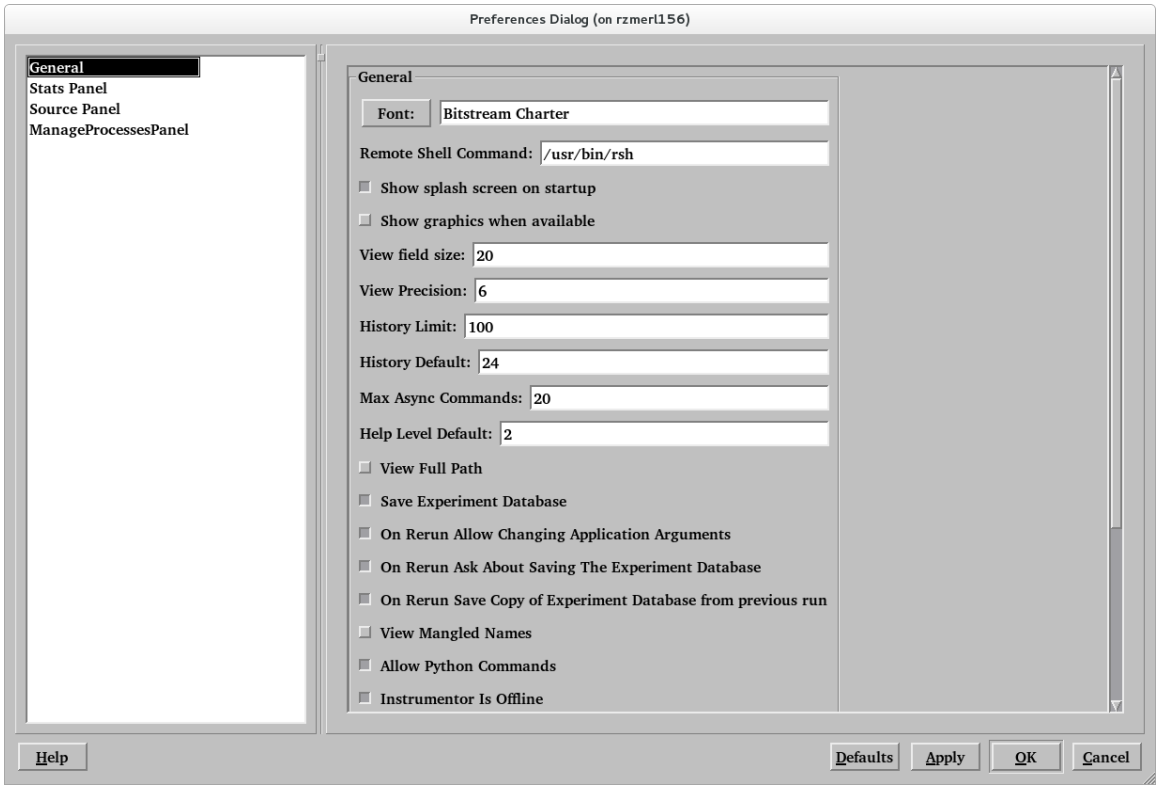
- Per Function – Display the performance information relative to each function in the program that had performance data gathered during the experiment that was run.
- Per Statement – Display the performance information relative to each statement in the program that had performance data gathered during the experiment that was run
- Per Linked Object – Display the performance information relative to each library or linked object in the program that had performance data gathered during the experiment that was run.
- Per Loop – Display the performance information relative to each loop in the program that had performance data gathered during the experiment that was run. Note that the loop performance information is only shown for loops that actually were executed. There may be loops in the application that will not show up in the display because they did were not executed or had minimal time attributed to them.

The image below illustrates that double clicking on a line of statistical information in the Stats Panel will focus the source panel at the line of source representing the performance information and annotates the source with that information. Note the hot to cold color highlighting of the source. The higher the performance values are the hotter the color. Red is the hottest color, so source highlighted in red is taking the most time in the program being profiled.

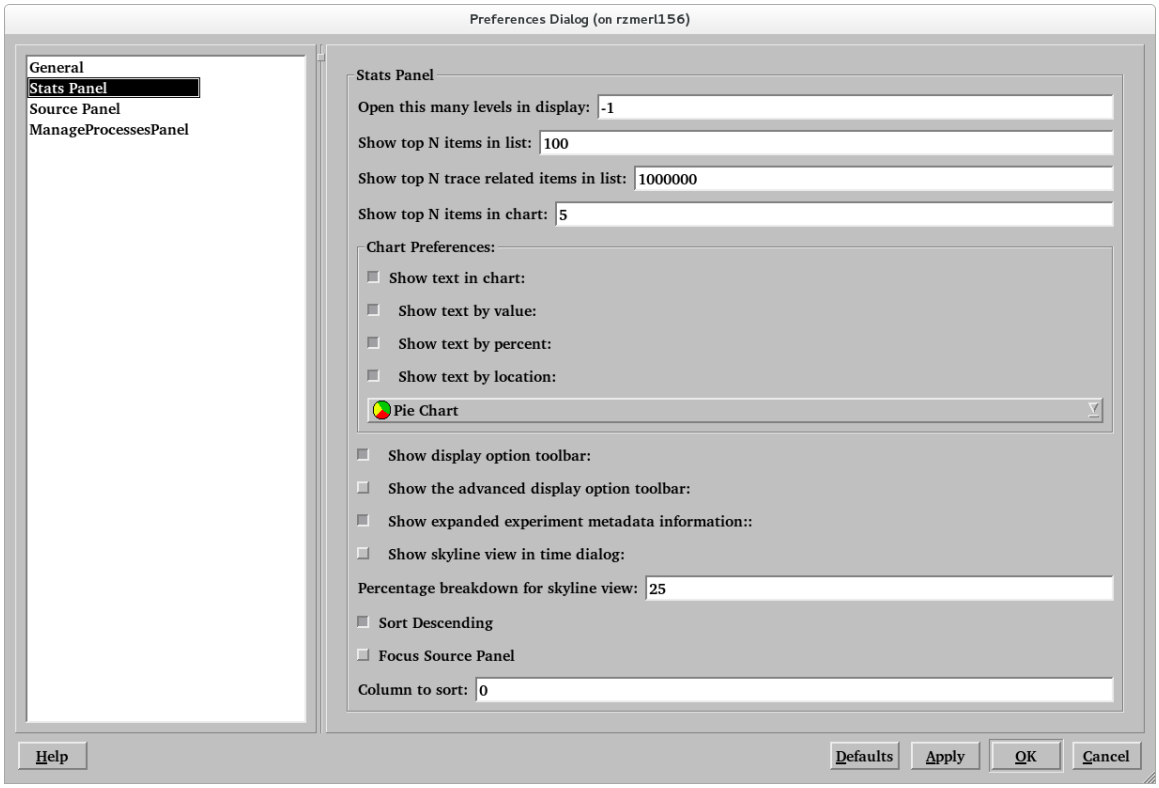


12.5.2 Preferences - How to change preferences

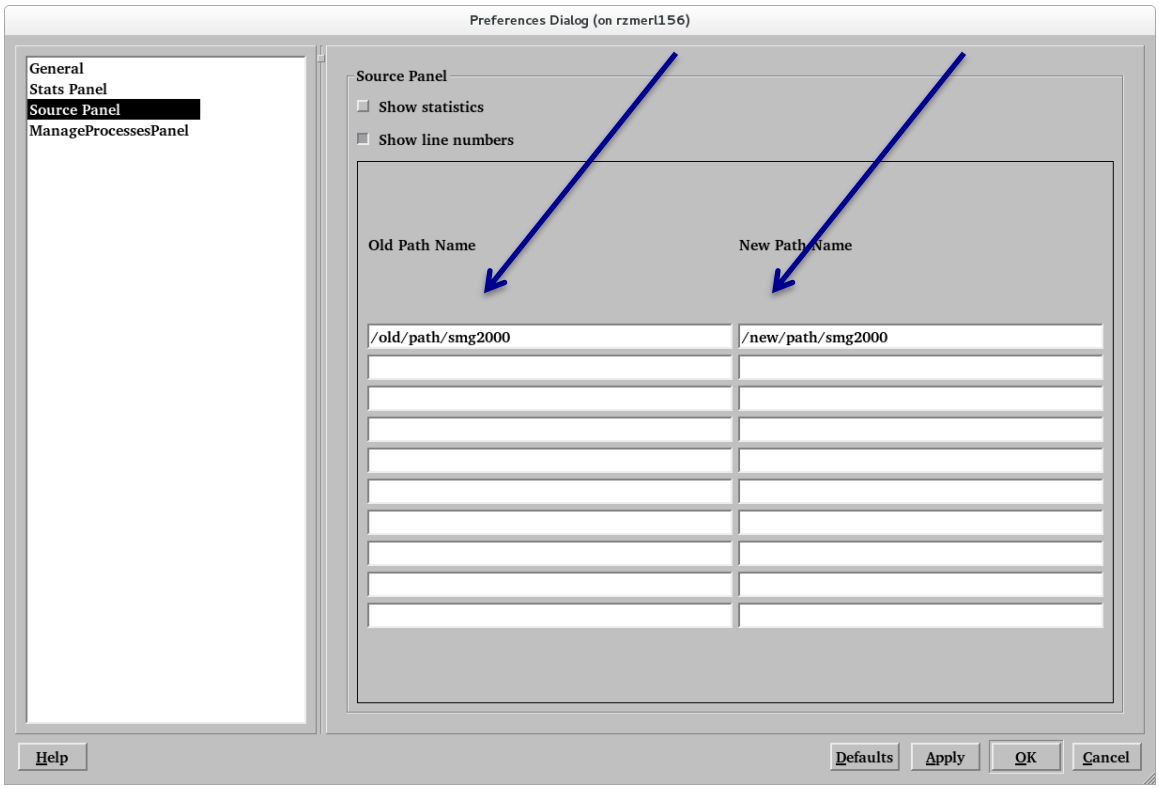
These preference panel views are included to outline the sequence for changing the GUI and CLI options for generating and viewing performance information with O|SS. The first view is the main (General) preference panel which allows the font, view field sizes, data precision, path, number of lines in the view, and many other general options.



The Stats Panel preference panel lets you change preferences related to viewing the performance information in the GUI Stats Panel.

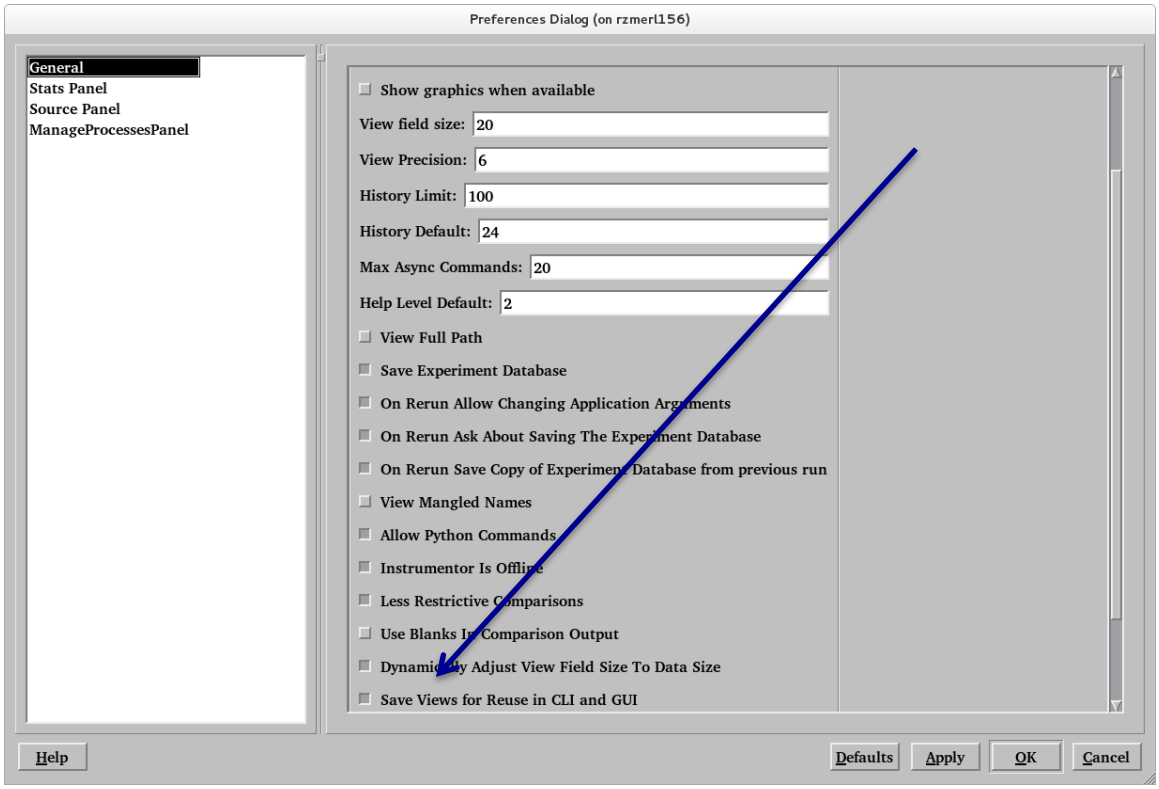


The Source Panel preference panel lets you remap paths to source files that are in a different location on the viewing platform. Use this when you can't see the source files on the viewing machine because the executable was built on a different machine. Put the old path to the source into the Old Path Name text box area and the new path for the source on the viewing machine into the New Path Name text box area.



12.5.2.1 Disabling or enabling the preference for Save/Reuse views in CLI.

Here we show the General preferences window scrolled down to the area of the view that shows more preference options. If you do not want the new save/reuse view active, then you can disable that function by clicking on the "Save Views for Reuse in CLI and GUI" (pointed to by the blue line below). By clicking on that preference line you can disable or enable the feature. The same procedure works for the other preferences as well.


Preferences Dialog (on rzmerl156)
General
Stats Panel
Source Panel
ManageProcessesPanel
Show graphics when available
View field size: 20
View Precision: 6
History Limit: 100
History Default: 24
Max Async Commands: 20
Help Level Default: 2
View Full Path
Save Experiment Database
On Rerun Allow Changing Application Arguments
On Rerun Ask About Saving The Experiment Database
On Rerun Save Copy of Experiment Database from previous run
View Mangled Names
Allow Python Commands
Instrumentor Is Offline
Less Restrictive Comparisons
Use Blanks In Comparison Output
Dynamically Adjust View Field Size To Data Size
Save Views for Reuse in CLI and GUI
Help
Defaults
Apply
OK
Cancel

13 Special System Support (Static Executables)

13.1 Cray and Blue Gene

When shared library support is limited the normal manner of running experiments in O|SS doesn't work. You must link the collectors into the static executable. Currently O|SS has static support on Cray and the Blue Gene P/Q platforms. You must relink the application with the osslink command to add support for the collectors.

The osslink command is a script that will help with linking. Calls to it are usually embedded inside an application's makefile. The user generally needs to fine the target that creates the actual static executable and create a collector target that links in the selected collector. The following is an example for re-linking the smg2000 application.

```
smg2000: smg2000.o
  @echo "Linking" $@ "... "
  ${CC} –o smg2000 smg2000.o ${LFLAGS}

smg2000-pcsamp: smg2000.o
  @echo "Linking" $@ "... "
  osslink –v -c pcsamp ${CC} -o smg2000-pcsamp smg2000.o ${LFLAGS}

smg2000-usertime: smg2000.o
  @echo "Linking" $@ "... "
  osslink -v -c usertime ${CC} -o smg2000-usertime smg2000.o ${LFLAGS}

smg2000-hwcsamp: smg2000.o
  @echo "Linking" $@ "... "
  osslink -v -c hwcsamp ${CC} -o smg2000-hwcsamp smg2000.o ${LFLAGS}

smg2000-io: smg2000.o
  @echo "Linking" $@ "... "
  osslink -v -c io ${CC} -o smg2000-io smg2000.o ${LFLAGS}

smg2000-iot: smg2000.o
  @echo "Linking" $@ "... "
  osslink -v -c iot ${CC} -o smg2000-iot smg2000.o ${LFLAGS}

smg2000-mpi: smg2000.o
  @echo "Linking" $@ "... "
  osslink -v -c mpi ${CC} –o smg2000-mpi smg2000.o ${LFLAGS}
```

Running the re-linked executable will cause the application to write the raw data files to the location specified by the environment variable OPENSS_RAWDATA_DIR. Normally, in the cluster environment where shared/dynamic executables are being run, the conversion from raw data to an O|SS database is done under the hood. However, in this case you must use the ossutil command to create the database file manually. Of course you can add the ossutil command to a batch script to eliminate

the step of manually issuing that command. Once you have the O|SS database files create you can view them normally with the GUI or CLI.

Below is an example of a job script that will execute these steps for you.

```
#PBS -q debug
#PBS -N smg2000-pcsamp
...
# must have a clean raw data directory each run
rm -rf /home/USER/smg2000/test/raw
mkdir /home/USER/smg2000/test/raw

setenv OPENSS_RAWDATA_DIR /home/USER/smg2000/test/raw
setenv OPENSS_DB_DIR /home/USER/smg2000/test/

cd /home/jgalaro/smg2000/test

# needs –b to have the original executable path available and match where
# the application was run when doing ossutil
aprun -b -n 16 /home/USER/smg2000/test/smg2000-pcsamp

# creates a X.0.openss database file, please
# load the module pointing to openspeedshop before accessing ossutil
ossutil /home/jgalaro/smg2000/test/raw
```

O|SS needs the executable path that is used to process symbols after the run is complete, to match where the executable was run. The executable path must match the path that is in the raw data that is written to the directory represented by OPENSS_RAWDATA_DIR. If the aprun "-b" option is not used, then the executable is run in a temporary system directory and the raw data reflects that directory path for the executable instead of the path where the executable is located when the job is initiated. This will cause ossutil to be unable to resolve the symbols.

There have been recent changes to the shared library support in O|SS. Dynamic shared library support is now available in newer Cray and Blue Gene operating systems. There is support for both shared and static binaries on the Cray and on the Blue Gene Q platforms.

13.1.1 osslink Command Information

The osslink command links the O|SS collectors and runtime libraries into the static executable and manages the setting the appropriate libraries based on the collector value that is one of the inputs to osslink. The help output for osslink follows.

```
osslink --help

Usage: /opt/osscbtf_cmake_only_july10/bin/osslink -c collector [options] compiler file ...

 -h, --help
```

```
 -c, --collector  <collector name>
Where collector is the name of the OpenSpeedShop collector to link into the application.  See the
openss man page for a description of the available experiments provided by OpenSpeedShop. This is
a mandatory option.

 -i | --mpitype
For MPI experiments, set the OPENSS_MPI_IMPLEMENTATION value to the MPI implementation
specified.  Valid options are:
      mpich
      mpich2
      mvapich
      mvapich2
      openmpi
      mpt
      lam
      lampi

 -v, --verbose
```

13.1.2 Cray Specific Static aprun Information

Note, in the above execution of the statically linked executable that we need to add the –b option to the aprun call. The option is needed because O|SS stores information about the executable location when it is running. Without the –b option the executable is run in a temporary location that is not available when the raw data information is being converted into the O|SS database file.

13.1.3 Changing parameters to the experiments

Note, when execution of the statically linked executable with the O|SS collectors linked in, the workflow is different. Since the more flexible convenience scripts can't be used, in order to change the arguments to the experiments, one must set environment variables.

Examples of the environment variables that can be changed are as follows:

Environment Variable	Represents	Experiment Type
OPENSS_PCSAMP_RATE	Sampling Rate.	pcsamp
OPENSS_USERTIME_RATE	Sampling Rate.	usertime
OPENSS_HWC_EVENT	PAPI or Native Event Name.	hwc
OPENSS_HWC_THRESHOLD	How many events occurrences before sample taken.	hwc
OPENSS_HWCSAMP_EVENTS	List of PAPI or Native Event Names.	hwcsamp
OPENSS_HWCSAMP_RATE	Sampling Rate.	hwcsamp

OPENSS_HWCTIME_EVENT	PAPI or Native Event Name.	hwctime
OPENSS_HWCTIME_THRESHOLD	How many events occurrences before sample taken.	hwctime
OPENSS_IO_TRACED	List of I/O functions to collect data for.	io
OPENSS_IOT_TRACED	List of I/O functions to collect data for.	iot
OPENSS_MPI_TRACED	List of MPI functions to collect data for.	mpi
OPENSS_MPIT_TRACED	List of MPI functions to collect data for.	mpit

14 Setup and Build for Open|SpeedShop

Open|SpeedShop (O|SS) is setup to work with a variety of processor types including Intel, AMD, Intel Phi, PPC, and ARM processor architectures. It has been tested on many Linux Distributions include SLES, SUSE, RHEL, Fedora Core, CentOS, Debian, Ubuntu and many others. It has been installed on the IBM Blue Gene and the Cray systems. The O|SS website contains information on special builds and usage instructions.

The source code for O|SS is available for download at the O|SS project home on Sourceforge:

http://sourceforge.net/projects/openss

Or CVS access is available at:

http://sourceforge.net/scm/?type=cvs&group_id=176777

Packages and additional information can be found on the O|SS website:

http://www.openspeedshop.org/

14.1 Open|SpeedShop Cluster Install

Open|SpeedShop (O|SS) comes with a set of bash install scripts that will build O|SS and any components it needs from source tarballs. First it will check to see if the correct supporting software is installed on your system, if the needed software isn't installed it will ask to build it for you. The only thing you need to do is provide a few arguments for the install script. For a normal setup you would just specify the directory to install in, what build task you want to do, and the location of your MPI and QT installs. For example:

```
./install-tool --build-krell-root --krell-root-prefix /opt/krellroot  --with-openmpi /opt/openmpi-1.8.2 –with-mvapich /opt/mvapich-1.7

./install-tool --build-offline --openss-prefix /opt/myoss --krell-root-prefix /opt/krellroot --with-openmpi /opt/openmpi-1.8.2 –with-mvapich /opt/mvapich-1.7
```

After the install has successfully completed there are a few important environment variables you need to set. Set a variable for the install location, so you can reuse it. Then set the OPENSS_PLUGIN_PATH for the directory where the plugins are stored. If you installed with more than one MPI version, you must specify which to use with OPENSS_MPI_IMPLEMENATION. Lastly, add the O|SS and Krell externals (root) bin directory to your PATH and lib64 directories to your LD_LIBRARY_PATH. Examples of the necessary environment variables that need to be set are as follows:

```
export oss_install_dir=/opt/myoss
export root_install-dir=/opt/krellroot
export OPENSS_MPI_IMPLEMENTATION=openmpi
export OPENSS_PLUGIN_PATH=$oss_install_dir/lib64/openspeedshop
```

```
export LD_LIBRARY_PATH=$root_install_dir/lib64:$LD_LIBRARY_PATH
export LD_LIBRARY_PATH=$oss_install_dir/lib64:$LD_LIBRARY_PATH
export DYNINSTAPI_RT_LIB=$root_install_dir/lib64/libdyninstAPI_RT.so
export PATH=$root_install_dir/bin:$PATH
export PATH=$oss_install_dir/bin:$PATH
```

14.2 Open|SpeedShop Blue Gene Platform Install

Please reference the O|SS 2.2 Build and Install Guide.

14.3 Open|SpeedShop Cray Platform Install

Please reference the O|SS 2.2 Build and Install Guide.

14.4 Execution Runtime Environment Setup

This section gives an example of a module file, softenv file and dotkit that can be used to set-up the O|SS execution environments.

14.4.1 Example module file

This is an example of a module file used for a cluster installation. Use module load <filename of module file> to activate the O|SS runtime environment.

```
#%Module1.0#####################################################################
#########
## openss modulefile
##
proc ModulesHelp { } {
      global version openss
      puts stderr "\topenss - loads the OpenSpeedShop software & application environment"
      puts stderr "\n\tThis adds $oss/* to several of the"
      puts stderr "\tenvironment variables."
      puts stderr "\n\tVersion $version\n"
}
module-whatis   "loads the OpenSpeedShop runtime environment"
# for Tcl script use only
set    version       2.2
set    oss      /opt/OSS21

setenv        OPENSS_PREFIX                $oss
setenv        OPENSS_DOC_DIR               $oss/share/doc/packages/OpenSpeedShop
prepend-path    PATH                       $oss/bin
prepend-path    MANPATH                          $oss/share/man

set unameexe  "/bin/uname"
if { [file exists $unameexe] } {
```

```
   set machinetype [ exec /bin/uname -m ]
   if { $machinetype == "x86" ||
        $machinetype == "i386" ||
        $machinetype == "i486" ||
        $machinetype == "i586" ||
        $machinetype == "i686" } {
      setenv  OPENSS_PLUGIN_PATH   $oss/lib/openspeedshop
      setenv DYNINSTAPI_RT_LIB $oss/lib/libdyninstAPI_RT.so
      prepend-path LD_LIBRARY_PATH $oss/lib
   }
   if { $machinetype == "x86_64" } {
      setenv  OPENSS_PLUGIN_PATH   $oss/lib64/openspeedshop
      setenv DYNINSTAPI_RT_LIB $oss/lib64/libdyninstAPI_RT.so
      prepend-path LD_LIBRARY_PATH $oss/lib64
   }
   if { $machinetype == "ia64" } {
      setenv  OPENSS_PLUGIN_PATH   $oss/lib/openspeedshop
      setenv DYNINSTAPI_RT_LIB $oss/lib/libdyninstAPI_RT.so
      prepend-path LD_LIBRARY_PATH $oss/lib
   }
}
```

14.4.2 Example softenv file

This is an example of a softenv file used for a Blue Gene/Q installation. Use the "resoft <filename of softenv file>" command to activate the O|SS runtime environment.

```
# The OpenSpeedShop .soft file.
# Remember to type "resoft" after working on this file.

OSS = /home/projects/oss/oss
TARCH = bgq

# Set up OSS environment variables

# Find the executable portions of OpenSpeedShop (order is important here)
PATH += $OSS/$TARCH/bin
PATH += $OSS/bin

# Find the libraries for OpenSpeedShop (order is important here)
LD_LIBRARY_PATH += $OSS/$TARCH/lib64
LD_LIBRARY_PATH += $OSS/lib64

# Find the runtime collectors
OPENSS_PLUGIN_PATH = $OSS/$TARCH/lib64/openspeedshop

# Tell the tool what the application MPI implementation is
# Needed if supporting multiple implementations and running the "mpi", "mpit" or "mpip" experiments
OPENSS_MPI_IMPLEMENTATION = mpich2

# Paths to documentation and man pages
OPENSS_DOC_DIR = $OSS/share/doc/packages/OpenSpeedShop
MANPATH = $OSS/share/man
```

```
# Use the basic environment.
@default
```

14.4.3 Example dotkit file

This is an example of a dotkit file used for a 64-bit cluster platform installation and is not generalized to support different platforms other than the 64-bit cluster it was written for. Use the "use <filename of dotkit file>" command to activate the O|SS runtime environment. Note: do not include the ".dk" portion of the filename when using the "use" command.

```
#c performance/profile
#d Open|SpeedShop (Version 2.2)
dk_setenv OPENSS_PREFIX /usr/global/tools/openspeedshop/oss-dev/OSS21
dk_setenv OPENSS_PLUGIN_PATH $OPENSS_PREFIX/lib64/openspeedshop
dk_setenv OPENSS_DOC $OPENSS_PREFIX/share/doc/packages/OpenSpeedShop/
dk_alter PATH          $OPENSS_PREFIX/bin
dk_alter LD_LIBRARY_PATH $OPENSS_PREFIX/lib64

dk_setenv DYNINSTAPI_RT_LIB $OPENSS_PREFIX/lib64/libdyninstAPI_RT.so
dk_setenv XPLAT_RSH rsh
dk_setenv OPENSS_MPI_IMPLEMENTATION mvapich
dk_test `dk_cev OPENSS_RAWDATA_DIR` -eq 0 && dk_setenv OPENSS_RAWDATA_DIR
/p/lscratchb/${USER}
```

15 Additional Information and Documentation Sources

15.1 Final Experiment Overview

In the table below we match up a few general questions you may ask yourself with the experiments you may want to run in order to find the answer.

Where does my code spend most of its time?
• Flat profiles (pcsamp) • Getting inclusive/exclusive timings with call paths (usertime) • Identifying hot call paths (usertime + HP analysis)
How do I analyze cache performance?
• Measure memory performance using hardware counters (hwc) • Compare to flat profiles (custom comparison) • Compare multiple hardware counters (N x hwc, hwcsamp)
How to identify I/O problems?
• Study time spent in I/O routines (io, iot and lightweight iop) • Compare runs under different scenarios (custom comparisons)
How to identify memory problems?
• Study time spent in memory allocation/de-allocation routines (mem) • Look for load imbalance (LB view) and outliers (CA view)
How do I find parallel inefficiencies in OpenMP and/or threaded applications?
• Study time spent in POSIX thread routines (pthreads) • Look for load imbalance (LB view) and outliers (CA view)

How do I find parallel inefficiencies in MPI applications?
• Study time spent in MPI routines (mpi, mpit, and lightweight mpip) • Look for load imbalance (LB view) and outliers (CA view)
How do I find parallel inefficiencies in NVIDIA CUDA applications?
• Study time spent in CUDA routines and the CUDA event execution trace. (cuda)

15.2 Additional Documentation

The python scripting API documentation can be found at http://www.openspeedshop.org/docs/pyscripting_doc or in the …/share/doc/packages/openspeedshop/pyscripting_doc folder in the install directory.

There are also man pages for openss and every convenience script. There's also a quick start guide that you can download from http://www.openspeedshop.org

There is also an O|SS Forum type email alias, where you can ask questions and read previous posts at oss-questions@openspeedshop.org. Use this URL to sign up: https://groups.google.com/a/krellinst.org/forum/?hl=en - !forum/oss-questions

There is also an email list that you can send your questions to without joining the group. The email alias is oss-contact@openspeedshop.org.

16 Convenience Script Basic Usage Reference Information

This section provides a quick overview of the convenience scripts that can be used to either compare experiment data to other experiment data or to gather performance information for each of the various performance metric types that O|SS supports.

16.1 Suggested Workflow

We recommend an **O|SS** workflow consisting of two phases. First, gathering the performance data using the convenience scripts. Then using the GUI or CLI to view the data.

16.2 Convenience Scripts

Users are encouraged to use the convenience scripts (for dynamically linked applications) that hide some of the underlying options for running experiments. The full command syntax can be found in the User's Guide. The script names correspond to the experiment types and are: **osspcsamp, ossusertime, osshwc, osshwcsamp, osshwctime, ossio, ossiot, ossmpi, ossmpit, ossiop, ossmem, ossomptp, osspthreads, ossmpip,** and **osscuda** plus an **osscompare** script. Note: If using the offline mode of operation, make sure to set **OPENSS_RAWDATA_DIR** (See **KEY ENVIRONMENT VARIABLES** section for info).

When running Open|SpeedShop, use the same syntax that is used to run the application/executable outside of O|SS, but enclosed in quotes; e.g.,

Using MPI drivers like mpirun: **osspcsamp "mpirun -np 512 ./smg2000 -n 5 5 5"**
Using SLURM/srun: **osspcsamp "srun -N 64 -n 512 ./smg2000 -n 5 5 5**"

Redirection to/from files inside quotes can be problematic, see convenience script "man" pages for more info.

16.3 Report and Database Creation

Running the pcsamp experiment on the sequential program named mexe: **osspcsamp** mexe results in a default report and the creation of a SQLite database file mexe-pcsamp.openss in the current directory; the report:

```
% CPU Time  CPU time   Function
48.990        11.650          f3 (mexe: m.c, 24)
33.478         7.960          f2 (mexe: m.c,15)
17.451         4.150          f1 (mexe: m.c,6)
 0.084         0.020          work(mexe:m.c,33)
```

To access alternative views in the GUI: **openss –f** mexe-pcsamp.openss loads the database file. Then use the GUI toolbar to select desired views; or, using the CLI: **openss –cli –f** mexe-pcsamp.openss to load the database file. Then use the **expview** command options for desired views.

16.4 osscompare: Compare Database Files

General form:
osscompare "<db_file1>, < db_file2>[,<db_file>...]" [time | percent | <other metrics>] [rows=nn] [viewtype=functions| statements | linkedobjects] > [oname = <csv filename>]

Where:

"<db_file>" represents an O|SS database file created by running an O|SS experiment on an application.

[time | percent | <other metrics>] represent the metric that the comparison will use to differentiate the performance information for each experiment database.

[rows=nn] indicates how many rows of output you want to have listed.

[viewtype=functions| statements | linkedobjects] select the granularity of the view output. The comparison is either done at the function, statement, or library view level. Function level is the default granularity.

[oname = <csv filename>] Name the output filename when comma separated list output is requested.

Example:
osscompare "smg-run1.openss,smg-run2.openss"
osscompare "smg-run1.openss,smg-run2.openss" percent rows=10

Please type "man osscompare" for more details.

16.5 osspcsamp: Program Counter Experiment

General form:
osspcsamp "<command> < args>" **[high | low | default |** <sampling rate>]

Sequential job example:
osspcsamp "smg2000 –n 50 50 50"

Parallel job example:
osspcsamp "mpirun –np 128 smg2000 –n 50 50 50"

Additional arguments:

high: twice the default sampling rate (samples per second)
low: half the default sampling rate
default: default sampling rate is 100
<sampling rate>: integer value sampling rate

16.6 ossusertime: Call Path Experiment

General form:
ossusertime "<command> < args>" [**high** | **low** | **default** | <sampling rate>]

Sequential job example:

ossusertime "smg2000 –n 50 50 50"

Parallel job example:
ossusertime "mpirun –np 64 smg2000 –n 50 50 50"

Additional arguments:

high: twice the default sampling rate (samples per second)
low: half the default sampling rate
default: default sampling rate is 35
<sampling rate>: integer value sampling rate

16.7 osshwc, osshwctime: HWC Experiments

General form:
osshwc[time] "<command> < args>" **[default |** <PAPI_event> | <PAPI threshold> | <PAPI_event><PAPI threshold>]

Sequential job example:
osshwc[time] "smg2000 –n 50 50 50"

Parallel job example:
osshwc[time] "mpirun –np 128 smg2000 –n 50 50 50"

Additional arguments:

default: event (PAPI_TOT_CYC), threshold (10000)
<PAPI_event>: PAPI event name
<PAPI threshold>: PAPI integer threshold

16.8 osshwcsamp: HWC Experiment

General form:
osshwcsamp "<command>< args>" **[default | <PAPI_event_list>| <sampling_rate>]**

Sequential job example:
osshwcsamp "smg2000 –n 50 50 50"

Parallel job examples:
osshwcsamp "mpirun –np 128 smg2000 –n 50 50 50"
osshwcsamp "srun –N 32 –n 128 sweep3d.mpi" PAPI_L1_DCM,PAPI_L1_DCA 200

Additional arguments:

default: events(PAPI_TOT_CYC and PAPI_FP_OPS), sampling_rate is 100
<PAPI_event_list>: Comma separated PAPI event list<sampling_rate>:Integer value sampling rate

16.9 ossio, ossiot: I/O Experiments

General form:
ossio[t] "<command> < args>" [**default** | f_t_list]

Sequential job example:
ossio[t] "smg2000 –n 50 50 50"

Parallel job example:
ossio[t] "mpirun –np 128 smg2000 –n 50 50 50"

Additional arguments:

default: trace all I/O functions
< f_t_list>: Comma-separated list of I/O functions to trace, one or more of the following: **close, creat, creat64, dup, dup2, lseek, lseek64, open, open64, pipe, pread, pread64, pwrite, pwrite64, read, readv, write, and writev**

16.10 ossmpi, ossmpip, ossmpit: MPI Experiments

General form:
ossmpi[p|t] "<mpirun><mpiargs><command><args>" [**default** | f_t_list]

Parallel job example:
ossmpi[p|t] "mpirun –np 128 smg2000 –n 50 50 50"

Additional arguments:

default: trace all MPI functions
<f_t_list>: Comma-separated list of MPI functions to trace, consisting of zero or more of: **MPI_Allgather,** .... **MPI_Waitsome** and/or zero or more of the MPI group categories:

MPI Category	Argument
All MPI Functions	all
Collective Communicators	collective_com
Persistent Communicators	persistent_com
Synchronous Point to Point	synchronous_p2p
Asynchronous Point to Point	asynchronous_p2p
Process Topologies	process_topologies
Groups Contexts Communicators	graphs_contexts_comms
Environment	environment
Datatypes	datatypes
MPI File I/O	fileio

16.11 ossmem: Memory Analysis Experiment

General form:
ossmem "<command> < args>" [**default** | f_t_list]

Sequential job example:
ossmem "smg2000 –n 50 50 50"

Parallel job example:
ossmem "mpirun –np 128 smg2000 –n 50 50 50"

Additional arguments:

default: trace all supported memory functions
<f_t_list>: Comma-separated list of exceptions to trace, consisting of one or more of: **malloc, free, memalign, posix_mem align, calloc and realloc**

16.12 ossomptp: OpenMP Specific Profiling Experiment

General form:
ossomptp "<command> < args>"

Sequential job example:
ossomptp "openmp_stress < stress.input"

Parallel job example:
ossomptp "mpirun –np 128 openMP_MD"

16.13 osspthreads: POSIX Thread Analysis Experiment

General form:
osspthreads "<command> < args>" [**default** | f_t_list]

Sequential job example:
osspthreads "smg2000 –n 50 50 50"

Parallel job example:
osspthreads "mpirun –np 128 smg2000 –n 50 50 50"

Additional arguments:

default: trace all POSIX thread functions
<f_t_list>: Comma-separated list of exceptions to trace, consisting of one or more of: **pthread_create, pthread_mutex_init, pthread_mutex_destroy, pthread_mutex_lock, pthread_mutex_trylock, pthread_mutex_unlock, pthread_cond_init, pthread_cond_destroy, pthread_cond_signal, pthread_cond_broadcast, pthread_cond_wait, and pthread_cond_timedwait**

16.14 osscuda: NVIDIA CUDA Tracing Experiment

General form:
osscuda "<command> < args>"

Sequential job example:
osscuda "eigenvalues --matrix-size=4096"

Parallel job example:
osscuda "mpirun -np 64 -npernode 1 lmp_linux -sf gpu < in.lj"

16.15 Key Environment Variables

EXECUTION RELATED VARIABLES	***DESCRIPTION***
OPENSS_RAWDATA_DIR	Used on cluster systems where a /tmp file system is unique on each node. It specifies the location of a shared file system path which is required for O|SS to save the "raw" data files on distributed systems. **OPENSS_RAWDATA_DIR="shared** file system path"Example: export **OPENSS_RAWDATA_DIR=/lustre4/fsys/userid**
OPENSS_ENABLE_MPI_PCONTROL	Activates the MPI_Pcontrol function recognition, otherwise MPI_Pcontrol function calls will be ignored by O|SS.
OPENSS_DATABASE_ONLY	When running the O|SS convenience scripts only create the database file and do NOT put out the default report. Used to reduce the size of the batch file output files if user is not interested in looking at the default report.
OPENSS_RAWDATA_ONLY	When running the O|SS convenience scripts only gather the performance information into the OPENSS_RAWDATA_DIR directory, but do NOT create the database file and do NOT put out the default report.
OPENSS_DB_DIR	Specifies the path to where O|SS will build the database file. On a file system without file locking enabled, the SQLite component cannot create the database file. This variable is used to specify a path to a file system with locking enabled for the database file creation. This usually occurs on Lustre file systems that don't have locking enabled.**OPENSS_DB_DIR="file** system path"Example: export **OPENSS_DB_DIR=/opt/filesys/userid**
OPENSS_MPI_IMPLEMENTATION	Specifies the MPI implementation in use by the application; only needed for the mpi, mpit, and mpip experiments. These are the currently supported MPI implementations: **openmpi, lampi, mpich, mpich2, mpt, lam, mvapich, mvapich2.** For Cray, IBM, Intel MPI implementations, use **mpich2.** **OPENSS_MPI_IMPLEMENTATION="MPI** impl. name" Example: export **OPENSS_MPI_IMPLEMENTATION=openmpi** In most cases, O|SS can auto-detect the MPI in use.
OPENSS_DEFER_VIEW	Allow overriding the displaying of the default view for cases where users may not want or need it to be displayed.