Oracle® Developer Studio 12.6: Performance Analyzer

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Contents

Using This Documentation

- **Overview** – Describes the performance analysis tools in the Oracle Developer Studio software. The Collector and Performance Analyzer are a pair of tools that perform statistical profiling of a wide range of performance data and tracing of various system calls, and relate the data to program structure at the function, source line, and instruction levels.
- **Audience** – Application developers, developer, architect, support engineer
- **Required knowledge** – Programming experience, Program/Software development testing, Aptitude to build and compile software products

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♦ ♦ ♦ CHAPTER 1

Overview of Performance Analyzer

Developing high performance applications requires a combination of compiler features, libraries of optimized functions, and tools for performance analysis. This *Performance Analyzer* manual describes the tools that are available to help you assess the performance of your code, identify potential performance problems, and locate the part of the code where the problems occur.

This chapter covers the following topics:

- "Tools of Performance Analysis" on page 17
- "Performance Analyzer Window" on page 20

Tools of Performance Analysis

This manual describes the Collector and Performance Analyzer, a pair of tools that you use to collect and analyze performance data for your application. The manual also describes the `er_print` utility, a command-line tool for displaying and analyzing collected performance data in text form. Performance Analyzer and the `er_print` utility show mostly the same data, but use different user interfaces.

The Collector and Performance Analyzer are designed for use by any software developer, even if performance tuning is not the developer's main responsibility. These tools provide a more flexible, detailed, and accurate analysis than the commonly used profiling tools `prof` and `gprof` and are not subject to an attribution error in `gprof`.

The Collector and Performance Analyzer tools help to answer the following kinds of questions:

- How much of the available resources does the program consume?
- Which functions or load objects are consuming the most resources?
- Which source lines and instructions are responsible for resource consumption?
- How did the program arrive at this point in the execution?
- Which resources are being consumed by a function or load object?

Collector Tool

The Collector tool collects performance data:

- Using a statistical method called profiling, which can be based on a clock trigger, or on the overflow of a hardware performance counter
- By tracing thread synchronization calls, memory allocation and deallocation calls, IO calls, and Message Passing Interface (MPI) calls
- As summary data on the system and the process

On Oracle Solaris platforms, clock profiling data includes microstate accounting data. All recorded profiling and tracing events include call stacks, as well as thread and CPU IDs.

The Collector can collect all kinds of data for C, C++ and Fortran programs, and it can collect profiling data for applications written in the Java™ programming language. It can collect data for dynamically-generated functions and for descendant processes. See Chapter 2, "Performance Data" for information about the data collected and Chapter 3, "Collecting Performance Data" for detailed information about the Collector. The Collector runs when you profile an application with Performance Analyzer, with the `collect` command, or with the `dbx collector` command.

Performance Analyzer Tool

Performance Analyzer displays the data recorded by the Collector so that you can examine the information. Performance Analyzer processes the data and displays various metrics of performance at the level of the program, its functions, source lines, and instructions. These metrics are classed into the following groups:

- Clock profiling metrics
- Hardware counter profiling metrics
- Synchronization wait tracing metrics
- I/O tracing metrics
- Heap tracing metrics
- MPI tracing metrics
- OpenMP metrics
- Static metrics
- Sample points

Performance Analyzer's Timeline view displays the raw data in a graphical format as a function of time. The Timeline view shows a chart of the events and the sample points recorded as a function of time. Data is displayed in horizontal bars.

Performance Analyzer can also display metrics of performance for structures in the dataspace of the target program, and for structural components of the memory subsystem. This data is an extension of the hardware counter metrics.

Experiments recorded on any supported architecture can be displayed by Performance Analyzer running on the same or any other supported architecture. For example, you can profile an application while it runs on an Oracle Solaris SPARC server and view the resulting experiment with Performance Analyzer running on a Linux machine.

A client version of Performance Analyzer called the Remote Performance Analyzer can be installed on any Oracle Solaris, Linux, Windows or Mac OS system that has Java available. You can run this remote Performance Analyzer and connect to a server where the full Oracle Developer Studio product is installed and view experiments remotely. See "Using Performance Analyzer Remotely" on page 137 for more information.

Performance Analyzer is used by other tools in the Oracle Developer Studio analysis suite:

- Thread Analyzer uses it for examining thread analysis experiments. A separate command `tha` starts Performance Analyzer with a specialized view to show data races and deadlocks in experiments that you can generate specifically for examining these types of data.

  *Oracle Developer Studio 12.6: Thread Analyzer User's Guide*describes how to use Thread Analyzer.
- The `uncover` code coverage utility uses Performance Analyzer to display coverage data in the Functions, Source, Disassembly, and Inst-Freq data views. See *Oracle Developer Studio 12.6: Discover and Uncover User's Guide* for more information.

See Chapter 4, "Performance Analyzer Tool" and the Help menu in Performance Analyzer for detailed information about using the tool.

Chapter 5, " `er_print` Command-Line Performance Analysis Tool" describes how to use the `er_print` command-line interface to analyze the data collected by the Collector.

Chapter 6, "Understanding Performance Analyzer and Its Data" discusses topics related to understanding the Performance Analyzer and its data, including how data collection works, interpreting performance metrics, call stacks and program execution.

Chapter 7, "Understanding Annotated Source and Disassembly Data" provides an understanding of the annotated source and disassembly, providing explanations about the different types of index lines and compiler commentary that Performance Analyzer displays. The chapter also describes the `er_src` command line utility that you can use to view annotated source code listings and disassembly code listings that include compiler commentary but do not include performance data.

Chapter 8, "Manipulating Experiments" describes how to copy, move, and delete experiments; add labels to experiments; and archive and export experiments.

Chapter 9, “Kernel Profiling” describes how you can use the Oracle Developer Studio performance tools to profile the kernel while the Oracle Solaris operating system is running a load.

Note - You can download demonstration code for Performance Analyzer in the sample applications zip file from the Oracle Developer Studio 12.6 web page at `http://www.oracle.com/technetwork/server-storage/developerstudio`.

See the *Oracle Developer Studio 12.6: Performance Analyzer Tutorials* for information about how to use the sample code with Performance Analyzer.

`er_print` Utility

The `er_print` utility presents in plain text all the displays that are presented by Performance Analyzer, with the exception of the Timeline display, the MPI Timeline display, and the MPI Chart display. These displays are inherently graphical and cannot be presented as text. For more information, see Chapter 5, “ `er_print` Command-Line Performance Analysis Tool” and `er_print`(1).

Performance Analyzer Window

This section provides a brief overview of Performance Analyzer's window layout. See Chapter 4, “Performance Analyzer Tool” and the Help menu for more information about the functionality and features discussed below.

When you start Performance Analyzer, a Welcome page makes it easy to start profiling an application in several different ways, view recent experiments, compare experiments, as well as navigate to documentation.

When you open an experiment, an Overview shows highlights of the data recorded and the set of metrics available. You can select which metrics you want to examine.

Performance Analyzer is organized around data views that you access from a navigation bar on the left side. Each view shows a different perspective of the performance data for your profiled application. The data views are connected so that when you select a function in one view, the other data views are updated to also focus on that selected function.

In most of the data views, you can use Performance Analyzer's powerful filtering technology to drill down into performance problems by selecting filters from a context menu or by clicking a filter button.

See the “Performance Analyzer Views” on page 109 for more information about each view.

You can navigate the Performance Analyzer from the keyboard as well as with a mouse.

♦ ♦ ♦ CHAPTER 2

Performance Data

The performance tools record data about specific events while a program is running, and convert the data into measurements of program performance called *metrics*. Metrics can be shown against functions, source lines, and instructions.

This chapter describes the data collected by the performance tools, how it is processed and displayed, and how it can be used for performance analysis. Because more than one tool collects performance data, the term *Collector* is used to refer to any of these tools. Likewise, because more than one tool analyzes performance data, the term *analysis tools* is used to refer to any of these tools.

This chapter covers the following topics.

- "Data the Collector Collects" on page 23
- "How Metrics Are Assigned to Program Structure" on page 38

See Chapter 3, "Collecting Performance Data" for information on collecting and storing performance data.

Data the Collector Collects

The Collector collects various kinds of data using several methods:

- **Profiling data** is collected by recording profile events at regular intervals. The interval is either a time interval obtained by using the system clock or a number of hardware events of a specific type. When the interval expires, a signal is delivered to the system and the data is recorded at the next opportunity.
- **Tracing data** is collected by interposing a wrapper function on various system functions and library functions so that calls to the functions can be intercepted and data recorded about the calls.
- **Sample data** is collected by calling various system routines to obtain global information.
- **Function and instruction count data** is collected by instrumenting the executable and any shared objects for the executable and for any shared objects that are dynamically opened or

statically linked to the executable and instrumented. The number of times each function or basic-block was executed is recorded.

- **Thread analysis data** is collected to support the Thread Analyzer.

Both profiling data and tracing data contain information about specific events, and both types of data are converted into performance metrics. Sample data is not converted into metrics, but is used to provide markers that can be used to divide the program execution into time segments. The sample data gives an overview of the program execution during that time segment.

The data packets collected at each profiling event or tracing event include the following information:

- A header identifying the data.
- A high-resolution timestamp.
- A thread ID.
- A processor (CPU) ID, when available from the operating system.
- A copy of the call stack. For Java programs, two call stacks are recorded: the machine call stack and the Java call stack.
- For OpenMP programs, an identifier for the current parallel region and the OpenMP state are also collected.

For more information on threads and lightweight processes, see Chapter 6, “Understanding Performance Analyzer and Its Data”.

In addition to the common data, each event-specific data packet contains information specific to the data type.

The data types and how you might use them are described in the following subsections:

- “Clock Profiling Data” on page 24
- “Hardware Counter Profiling Data” on page 28
- “Synchronization Wait Tracing Data” on page 31
- “Heap Tracing (Memory Allocation) Data” on page 32
- “I/O Tracing Data” on page 33
- “MPI Tracing Data” on page 35
- “Sample Data” on page 34

Clock Profiling Data

When you are doing clock profiling, the data collected depends on the information provided by the operating system.

Clock Profiling Under Oracle Solaris

In clock profiling under Oracle Solaris, the state of each thread is stored at regular time intervals. This time interval is called the profiling interval. The data collected is converted into times spent in each state, with a resolution of the profiling interval.

The default profiling interval is approximately 10 milliseconds (10 ms). You can specify a high-resolution profiling interval of approximately 1 ms and a low-resolution profiling interval of approximately 100 ms. If the operating system permits you can also specify a custom interval. Run the `collect -h` command with no other arguments to print the range and resolution allowable on the system.

The following table shows the performance metrics that Performance Analyzer and `er_print` can display when an experiment contains clock profiling data. Note that the metrics from all threads are added together.

TABLE 1 Timing Metrics from Clock Profiling on Oracle Solaris

Metric	Definition
Total thread time	Sum of time that threads spent in all states.
Total CPU time	Thread time spent running on the CPU in either user, kernel, or trap mode
User CPU time	Thread time spent running on the CPU in user mode.
System CPU time	Thread time spent running on the CPU in kernel mode.
Trap CPU time	Thread time spent running on the CPU in trap mode.
User lock time	Thread time spent waiting for a synchronization lock.
Data page fault time	Thread time spent waiting for a data page.
Text page fault time	Thread time spent waiting for a text page.
Kernel page fault time	Thread time spent waiting for a kernel page.
Stopped time	Thread time spent stopped.
Wait CPU time	Thread time spent waiting for the CPU.
Sleep time	Thread time spent sleeping

Timing metrics tell you where your program spent time in several categories and can be used to improve the performance of your program.

- High user CPU time tells you where the program did most of the work. You can use it to find the parts of the program where you might gain the most from redesigning the algorithm.
- High system CPU time tells you that your program is spending a lot of time in calls to system routines.
- High wait CPU time tells you that more threads are ready to run than there are CPUs available, or that other processes are using the CPUs.

- High user lock time tells you that threads are unable to obtain the lock that they request.
- High text page fault time means that the code ordered by the linker is organized in memory so that many calls or branches cause a new page to be loaded.
- High data page fault time indicates that access to the data is causing new pages to be loaded. Reorganizing the data structure or the algorithm in your program can fix this problem.

Clock Profiling Under Linux

On Linux platforms, the clock data can only be shown as Total CPU time. Linux CPU time is the sum of user CPU time and system CPU time.

Clock Profiling for OpenMP Programs

If clock profiling is performed on an OpenMP program, additional metrics are provided: Master Thread Time, OpenMP Work, and OpenMP Wait.

- On Oracle Solaris, Master Thread Time is the total time spent in the master thread and corresponds to wall-clock time. The metric is not available on Linux.
- On Oracle Solaris, OpenMP Work accumulates when work is being done either serially or in parallel. OpenMP Wait accumulates when the OpenMP runtime is waiting for synchronization, and accumulates whether the wait is using CPU time or sleeping, or when work is being done in parallel but the thread is not scheduled on a CPU.
- On the Linux operating system, OpenMP Work and OpenMP Wait are accumulated only when the process is active in either user or system mode. Unless you have specified that OpenMP should do a busy wait, OpenMP Wait on Linux is not useful.

Data for OpenMP programs can be displayed in any of three view modes. In User mode, slave threads are shown as if they were really cloned from the master thread, and have call stacks matching those from the master thread. Frames in the call stack coming from the OpenMP runtime code (`libmtsk.so`) are suppressed. In Expert user mode, the master and slave threads are shown differently, and the explicit functions generated by the compiler are visible, and the frames from the OpenMP runtime code (`libmtsk.so`) are suppressed. For Machine mode, the actual native stacks are shown.

Clock Profiling for the Oracle Solaris Kernel

The `er_kernel` utility can collect clock-based profile data on the Oracle Solaris kernel. You can profile the kernel by running the `er_kernel` utility directly from the command line or by choosing Profile Kernel from the File menu in Performance Analyzer.

The `er_kernel` utility captures kernel profile data and records the data as a Performance Analyzer experiment in the same format as an experiment created on user programs by the `collect` utility. The experiment can be processed by the `er_print` utility or Performance Analyzer. A kernel experiment can show function data, caller-callee data, instruction-level data, and a timeline, but not source-line data (because most Oracle Solaris modules do not contain line-number tables).

`er_kernel` can also record a user-level experiment on any processes running at the time, for which the user has permissions. Such experiments are similar to experiments that `collect` creates but have data only for User CPU Time and System CPU Time, and do not have support for Java or OpenMP profiling.

See Chapter 9, "Kernel Profiling" for more information.

Clock Profiling for MPI Programs

Clock profiling data can be collected on an MPI experiment that is run with Oracle Message Passing Toolkit, formerly known as Sun HPC ClusterTools. The Oracle Message Passing Toolkit must be at least version 8.1.

The Oracle Message Passing Toolkit is available as part of the Oracle Solaris 11 release. If it is installed on your system, you can find it in `/usr/openmpi`. If it is not already installed on your Oracle Solaris 11 system, you can search for the package with the command `pkg search openmpi` if a package repository is configured for the system. See *Adding and Updating Software in Oracle Solaris 11* for more information about installing software in Oracle Solaris 11.

When you collect clock profiling data on an MPI experiment, you can view two additional metrics:

- MPI Work, which accumulates when the process is inside the MPI runtime doing work, such as processing requests or messages
- MPI Wait, which accumulates when the process is inside the MPI runtime but waiting for an event, buffer, or message

On Oracle Solaris, MPI Work accumulates when work is being done either serially or in parallel. MPI Wait accumulates when the MPI runtime is waiting for synchronization, and accumulates whether the wait is using CPU time or sleeping, or when work is being done in parallel but the thread is not scheduled on a CPU.

On Linux, MPI Work and MPI Wait are accumulated only when the process is active in either user or system mode. Unless you have specified that MPI should do a busy wait, MPI Wait on Linux is not useful.

Note - Other versions of MPI are supported. To see the full list, type `collect` with no arguments.

Note - If your are using Linux with Oracle Message Passing Toolkit 8.2 or 8.2.1, you might need a workaround. The workaround is not needed for version 8.1 or 8.2.1c, or for any version if you are using an Oracle Developer Studio compiler.

The Oracle Message Passing Toolkit version number is indicated by the installation path such as `/opt/SUNWhpc/HPC8.2.1`, or you can type `mpirun –V` to see output as follows where the version is shown in italics:

`mpirun (Open MPI) 1.3.4r22104-`*ct8.2.1*`-b09d-r70`

If your application is compiled with a GNU or Intel compiler, and you are using Oracle Message Passing Toolkit 8.2 or 8.2.1 for MPI, to obtain MPI state data you must use the `-WI` and `--enable-new-dtags` options with the Oracle Message Passing Toolkit `link` command. These options cause the executable to define `RUNPATH` in addition to `RPATH`, allowing the MPI State libraries to be enabled with the `LD_LIBRARY_PATH` environment variable.

Hardware Counter Profiling Data

Hardware counters keep track of events like cache misses, cache stall cycles, floating-point operations, branch mispredictions, CPU cycles, and instructions executed. In hardware counter profiling, the Collector records a profile packet when a designated hardware counter of the CPU on which a thread is running overflows. The counter is reset and continues counting. The profile packet includes the overflow value and the counter type.

Various processor chip families support from two to eighteen simultaneous hardware counter registers. The Collector can collect data on one or more registers. For each register you can select the type of counter to monitor for overflow, and set an overflow value for the counter. Some hardware counters can use any register, while others are only available on a particular register. Consequently, not all combinations of hardware counters can be chosen in a single experiment.

Hardware counter profiling can also be done on the kernel in Performance Analyzer and with the `er_kernel` utility. See Chapter 9, “Kernel Profiling” for more information.

Hardware counter profiling data is converted by Performance Analyzer into count metrics. For counters that count in cycles, the metrics reported are converted to times. For counters that do not count in cycles, the metrics reported are event counts. On machines with multiple CPUs, the clock frequency used to convert the metrics is the harmonic mean of the clock frequencies of the individual CPUs. Because each type of processor has its own set of hardware counters, and because the number of hardware counters is large, the hardware counter metrics are not listed here. "Hardware Counter Lists" on page 29 tells you how to find out what hardware counters are available.

If two specific counters, "cycles" and "insts", are collected, two additional metrics are available, "CPI" and "IPC", meaning cycles-per-instruction and instructions-per-cycle", respectively. They are always shown as a ratio, and not as a time, count, or percentage. A high value of CPI or low value of IPC indicates code that runs inefficiently in the machine; conversely, a low value of CPI or a high value of IPC indicates code that runs efficiently in the pipeline.

One use of hardware counters is to diagnose problems with the flow of information into and out of the CPU. High counts of cache misses, for example, indicate that restructuring your program to improve data or text locality or to increase cache reuse can improve program performance.

Some of the hardware counters correlate with other counters. For example, branch mispredictions and instruction cache misses are often related because a branch misprediction causes the wrong instructions to be loaded into the instruction cache. These must be replaced by the correct instructions. The replacement can cause an instruction cache miss, an instruction translation lookaside buffer (ITLB) miss, or even a page fault.

For many hardware counters, the overflows are often delivered one or more instructions after the instruction that caused the overflow event. Such behavior is referred to as "skid", and it can make counter overflow profiles difficult to interpret: the performance data will be associated with an instruction executed after the one that actually caused the observed event. For many chips and counters, the number of instructions skidded over is not deterministic; for some it is precisely deterministic (usually zero or one).

Some memory-related counters have a deterministic skid and are available for Memoryspace Profiling. They are labelled as "precise load-store" counters in the list described in "Hardware Counter Lists" on page 29. For such counters, the triggering PC and EA can be determined and memoryspace/dataspace data are captured by default. See "Dataspace Profiling and Memoryspace Profiling" on page 201 for more information.

Hardware Counter Lists

Hardware counters are processor-specific, so the choice of counters available depends on the processor that you are using. The performance tools provide aliases for a number of counters that are likely to be in common use. You can determine the maximum number of hardware counters definitions for profiling on the current machine, and see the full list of available hardware counters, as well as the default counter set, by running `collect -h` with no other arguments on the current machine.

If the processor and system support hardware counter profiling, the `collect -h` command prints two lists containing information about hardware counters. The first list contains hardware counters that are aliased to common names. The second list contains raw hardware counters. If neither the performance counter subsystem nor the `collect` command have the names for the counters on a specific system, the lists are empty. In most cases, however, the counters can be specified numerically.

The following example shows entries in the counter list. The counters that are aliased are displayed first in the list, followed by a list of the raw hardware counters. Each line of output in this example is formatted for print.

```
    Aliases for most useful HW counters:

    alias      raw name                    type      units regs description

    cycles     Cycles_user                      CPU-cycles 0123 CPU Cycles
    insts      Instr_all                            events 0123 Instructions Executed
    c_stalls   Commit_0_cyc                     CPU-cycles 0123 Stall Cycles
    loads      Instr_ld       precise load-store    events 0123 Load Instructions
    stores     Instr_st       precise load-store    events 0123 Store Instructions
    dcm        DC_miss_commit precise load-store    events 0123 L1 D-cache Misses
...

Raw HW counters:

    name                                   type      units regs description

    Sel_pipe_drain_cyc                          CPU-cycles 0123
    Sel_0_wait_cyc                              CPU-cycles 0123
    Sel_0_ready_cyc                             CPU-cycles 0123
...
```

Format of the Aliased Hardware Counter List

In the aliased hardware counter list, the first field (for example, `cycles`) gives the alias name that can be used in the `-h` *counter*... argument of the `collect` command. This alias name is also the identifier to use in the `er_print` command.

The second field gives the raw name of the counter. For example, `loads` is short for `Instr_ld`

The third field contains type information, which might be empty (for example, `precise load-store`).

Possible entries in the type information field include the following:

- `memoryspace`, the memory-based counter interrupt occurs with a known, precise skid, and is supported for memoryspace profiling. For such counters the Performance Analyzer can, and by default will, collect memoryspace and dataspace data. See the "MemoryObjects Views" on page 122 description for details.

- `load`, `store`, or `load-store`, the counter is memory-related.
- `not-program-related`, the counter captures events initiated by some other program, such as CPU-to-CPU cache snoops. Using the counter for profiling generates a warning and profiling does not record a call stack.

The fourth field contains the type of units being counted (for example, `events`).

The unit can be one of the following:

- `CPU-cycles`, the counter can be used to provide a time-based metric. The metrics reported for such counters are converted by default to inclusive and exclusive times, but can optionally be shown as event counts.
- `events`, the metric is inclusive and exclusive event counts, and cannot be converted to a time.

The fifth field lists the available registers for the counter. For example, `0123`.

The sixth field gives a short description of the counter, for example `Load Instructions`.

Format of the Raw Hardware Counter List

The information included in the raw hardware counter list is a subset of the information in the aliased hardware counter list. Each line in the raw hardware counter list includes the internal counter name as used by `cputrack`(1), the type information, the counter units, which can be either `CPU-cycles` or `events`, and the register numbers on which that counter can be used.

If the counter measures events unrelated to the program running, the first word of type information is `not-program-related`. For such a counter, profiling does not record a call stack, but instead shows the time being spent in an artificial function, `collector_not_program_related` . Thread and LWP IDs are recorded, but are meaningless.

The default overflow value for raw counters is 1000003. This value is not ideal for most raw counters, so you should specify overflow values when specifying raw counters.

Synchronization Wait Tracing Data

In multithreaded programs, the synchronization of tasks performed by different threads can cause delays in execution of your program. For example, one thread might have to wait for access to data that has been locked by another thread. These events are called synchronization delay events and are collected by tracing calls to the Solaris or pthread thread functions. The process of collecting and recording these events is called synchronization wait tracing. The time spent waiting for the lock is called the synchronization wait time.

Events are only recorded if their wait time exceeds a threshold value, which is given in microseconds. A threshold value of 0 means that all synchronization delay events are traced, regardless of wait time. The default threshold is determined by running a calibration test, in which calls are made to the threads library without any synchronization delay. The threshold is the average time for these calls multiplied by an arbitrary factor (currently 6). This procedure prevents the recording of events for which the wait times are due only to the call itself and not to a real delay. As a result, the amount of data is greatly reduced, but the count of synchronization events can be significantly underestimated.

For Java programs, synchronization tracing might cover Java method calls in the profiled program, native synchronization calls, or both.

Synchronization wait tracing data is converted into the metrics in the following table.

TABLE 2 Synchronization Wait Tracing Metrics

Metric	Definition
Synchronization delay event count.	The number of calls to a synchronization routine where the wait time exceeded the prescribed threshold.
Synchronization wait time.	Total of wait times that exceeded the prescribed threshold.

From this information you can determine whether functions or load objects are either frequently blocked or experience unusually long wait times when they do make a call to a synchronization routine. High synchronization wait times indicate contention among threads. You can reduce the contention by redesigning your algorithms, particularly restructuring your locks so that they cover only the data for each thread that needs to be locked.

Heap Tracing (Memory Allocation) Data

Calls to memory allocation and deallocation functions that are not properly managed can be a source of inefficient data usage and can result in poor program performance. In heap tracing, the Collector traces memory allocation and deallocation requests by interposing on the C standard library memory allocation functions `malloc`, `realloc`, `valloc`, and `memalign` and the deallocation function `free`. Calls to `mmap` are treated as memory allocations, which enables heap tracing events for Java memory allocations to be recorded. The Fortran functions `allocate` and `deallocate` call the C standard library functions, so these routines are traced indirectly.

Heap profiling for Java programs is not supported.

Heap tracing data is converted into the following metrics.

TABLE 3 Memory Allocation (Heap Tracing) Metrics

Metric	Definition
Allocations	The number of calls to the memory allocation functions
Bytes allocated	The sum of the number of bytes allocated in each call to the memory allocation functions
Leaks	The number of calls to the memory allocation functions that did not have a corresponding call to a deallocation function
Bytes leaked	The number of bytes that were allocated but not deallocated

Collecting heap tracing data can help you identify memory leaks in your program or locate places where there is inefficient allocation of memory.

When you look at the Leaks view with filters applied, the leaks shown are for memory allocations that were done under the filtering criteria and not deallocated at any time. Leaks are not restricted to those allocations that are not deallocated under the filtering criteria.

A memory leak here is defined as a block of memory that is dynamically allocated, but never freed, independent of whether a pointer to it exists in the process address space. (Other tools might define a leak differently, as a block of memory that is allocated, not freed, but which no longer has a pointer to it in the process address space.)

I/O Tracing Data

I/O data collection traces input/output system calls including reads and writes. It measures the duration of the calls, tracks the files and descriptors, and the amount of data transferred. You can use the I/O metrics to identify the files, file handles, and call stacks that have high byte transfer volumes and total thread time.

TABLE 4 I/O Tracing Metrics

Metric	Definition
Read Bytes	The sum of the number of bytes read in each call to the read functions.
Write Bytes	The sum of the number of bytes written in each call to the write functions.
Read Count	Number of times read calls were made.
Write Count	Number of times write calls were made.
Other I/O Count	Number of times other IO calls were made

Metric	Definition
I/O Error Count	Number of errors made during IO calls
Read Time	Number of seconds spent reading data
Write Time	Number of seconds spent writing data
Other I/O Time	Number of seconds spent performing other IO calls
I/O Error Time	Number of seconds spent in IO errors

Sample Data

Process-wide resource-utilization samples contain statistics from the kernel such as page fault and I/O data, context switches, and a variety of page residency (working-set and paging) statistics. The data is attributed to the process and does not map to function-level metrics. Process-wide resource-utilization samples are recorded in the following circumstances:

Sample packets are recorded in the following circumstances:

- When the program stops for any reason during debugging in `dbx`, such as at a breakpoint if the option to do this is set.
- At the end of a sampling interval if you have selected periodic sampling. The sampling interval is specified as an integer in units of seconds. The default value is 1 second.
- When you use the `dbx collector sample record` command to manually record a sample.
- At a call to `collector_sample` if you have put calls to this routine in your code (see "Program Control of Data Collection Using libcollector Library" on page 55).
- When a specified signal is delivered if you have used the `-l` option with the `collect` command (see the `collect(1)` man page).
- When collection is initiated and terminated.
- When you pause collection with the `dbx collector pause` command (just before the pause) and when you resume collection with the `dbx collector resume` command (just after the resume).
- Before and after a descendant process is created.

The performance tools use the data recorded in the sample packets to group the data into time periods, which are called samples. You can filter the event-specific data by selecting a set of samples so that you see only information for these particular time periods. You can also view the global data for each sample.

The performance tools make no distinction between the different kinds of sample points. To make use of sample points for analysis you should choose only one kind of point to be recorded. In particular, if you want to record sample points that are related to the program structure or execution sequence, you should turn off periodic sampling and use samples recorded when dbx stops the process, or when a signal is delivered to the process that is recording data using the collect command, or when a call is made to the Collector API functions.

MPI Tracing Data

The Collector can collect data on calls to the Message Passing Interface (MPI) library.

MPI tracing is implemented using the open source VampirTrace 5.5.3 release. It recognizes the following VampirTrace environment variables:

VT_STACKS	Controls whether call stacks are recorded in the data. The default setting is 1. Setting VT_STACKS to 0 disables call stacks.
VT_BUFFER_SIZE	Controls the size of the internal buffer of the MPI API trace collector. The default value is 64M (64 MBytes).
VT_MAX_FLUSHES	Controls the number of times the buffer is flushed before terminating MPI tracing. The default value is 0, which sets the buffer to be flushed to disk whenever it is full. Setting VT_MAX_FLUSHES to a positive number sets a limit for the number of times the buffer is flushed.
VT_VERBOSE	Turns on various error and status messages. The default value is 1, which turns on critical error and status messages. Set the variable to 2 if problems arise.

For more information on these variables, see the *Vampirtrace User Manual* on the Technische Universität Dresden web site.

MPI events that occur after the buffer limits have been reached are not written into the trace file resulting in an incomplete trace.

To remove the limit and get a complete trace of an application, set the VT_MAX_FLUSHES environment variable to 0. This setting causes the MPI API trace collector to flush the buffer to disk whenever the buffer is full.

To change the size of the buffer, set the VT_BUFFER_SIZE environment variable. The optimal value for this variable depends on the application that is to be traced. Setting a small value increases the memory available to the application but triggers frequent buffer flushes by the MPI API trace collector. These buffer flushes can significantly change the behavior of the application. On the other hand, setting a large value such as 2G minimizes buffer flushes by the MPI API trace collector but decreases the memory available to the application. If not enough memory is available to hold the buffer and the application data, parts of the application might be swapped to disk, leading to a significant change in the behavior of the application.

The following list shows the functions for which data is collected.

`MPI_Abort`	`MPI_Accumulate`	`MPI_Address`
`MPI_Allgather`	`MPI_Allgatherv`	`MPI_Allreduce`
`MPI_Alltoall`	`MPI_Alltoallv`	`MPI_Alltoallw`
`MPI_Attr_delete`	`MPI_Attr_get`	`MPI_Attr_put`
`MPI_Barrier`	`MPI_Bcast`	`MPI_Bsend`
`MPI_Bsend-init`	`MPI_Buffer_attach`	`MPI_Buffer_detach`
`MPI_Cancel`	`MPI_Cart_coords`	`MPI_Cart_create`
`MPI_Cart_get`	`MPI_Cart_map`	`MPI_Cart_rank`
`MPI_Cart_shift`	`MPI_Cart_sub`	`MPI_Cartdim_get`
`MPI_Comm_compare`	`MPI_Comm_create`	`MPI_Comm_dup`
`MPI_Comm_free`	`MPI_Comm_group`	`MPI_Comm_rank`
`MPI_Comm_remote_group`	`MPI_Comm_remote_size`	`MPI_Comm_size`
`MPI_Comm_split`	`MPI_Comm_test_inter`	`MPI_Dims_create`
`MPI_Errhandler_create`	`MPI_Errhandler_free`	`MPI_Errhandler_get`
`MPI_Errhandler_set`	`MPI_Error_class`	`MPI_Error_string`
`MPI_File_close`	`MPI_File_delete`	`MPI_File_get_amode`
`MPI_File_get_atomicity`	`MPI_File_get_byte_offset`	`MPI_File_get_group`
`MPI_File_get_info`	`MPI_File_get_position`	`MPI_File_get_position_shared`
`MPI_File_get_size`	`MPI_File_get_type_extent`	`MPI_File_get_view`
`MPI_File_iread`	`MPI_File_iread_at`	`MPI_File_iread_shared`
`MPI_File_iwrite`	`MPI_File_iwrite_at`	`MPI_File_iwrite_shared`
`MPI_File_open`	`MPI_File_preallocate`	`MPI_File_read`
`MPI_File_read_all`	`MPI_File_read_all_begin`	`MPI_File_read_all_end`
`MPI_File_read_at`	`MPI_File_read_at_all`	`MPI_File_read_at_all_begin`
`MPI_File_read_at_all_end`	`MPI_File_read_ordered`	`MPI_File_read_ordered_begin`
`MPI_File_read_ordered_end`	`MPI_File_read_shared`	`MPI_File_seek`
`MPI_File_seek_shared`	`MPI_File_set_atomicity`	`MPI_File_set_info`
`MPI_File_set_size`	`MPI_File_set_view`	`MPI_File_sync`
`MPI_File_write`	`MPI_File_write_all`	`MPI_File_write_all_begin`
`MPI_File_write_all_end`	`MPI_File_write_at`	`MPI_File_write_at_all`
`MPI_File_write_at_all_begin`	`MPI_File_write_at_all_end`	`MPI_File_write_ordered`
`MPI_File_write_ordered_begin`	`MPI_File_write_ordered_end`	`MPI_File_write_shared`

`MPI_Finalize`	`MPI_Gather`	`MPI_Gatherv`
`MPI_Get`	`MPI_Get_count`	`MPI_Get_elements`
`MPI_Get_processor_name`	`MPI_Get_version`	`MPI_Graph_create`
`MPI_Graph_get`	`MPI_Graph_map`	`MPI_Graph_neighbors`
`MPI_Graph_neighbors_count`	`MPI_Graphdims_get`	`MPI_Group_compare`
`MPI_Group_difference`	`MPI_Group_excl`	`MPI_Group_free`
`MPI_Group_incl`	`MPI_Group_intersection`	`MPI_Group_rank`
`MPI_Group_size`	`MPI_Group_translate_ranks`	`MPI_Group_union`
`MPI_Ibsend`	`MPI_Init`	`MPI_Init_thread`
`MPI_Intercomm_create`	`MPI_Intercomm_merge`	`MPI_Irecv`
`MPI_Irsend`	`MPI_Isend`	`MPI_Issend`
`MPI_Keyval_create`	`MPI_Keyval_free`	`MPI_Op_create`
`MPI_Op_free`	`MPI_Pack`	`MPI_Pack_size`
`MPI_Probe`	`MPI_Put`	`MPI_Recv`
`MPI_Recv_init`	`MPI_Reduce`	`MPI_Reduce_scatter`
`MPI_Request_free`	`MPI_Rsend`	`MPI_rsend_init`
`MPI_Scan`	`MPI_Scatter`	`MPI_Scatterv`
`MPI_Send`	`MPI_Send_init`	`MPI_Sendrecv`
`MPI_Sendrecv_replace`	`MPI_Ssend`	`MPI_Ssend_init`
`MPI_Start`	`MPI_Startall`	`MPI_Test`
`MPI_Test_cancelled`	`MPI_Testall`	`MPI_Testany`
`MPI_Testsome`	`MPI_Topo_test`	`MPI_Type_commit`
`MPI_Type_contiguous`	`MPI_Type_extent`	`MPI_Type_free`
`MPI_Type_hindexed`	`MPI_Type_hvector`	`MPI_Type_indexed`
`MPI_Type_lb`	`MPI_Type_size`	`MPI_Type_struct`
`MPI_Type_ub`	`MPI_Type_vector`	`MPI_Unpack`
`MPI_Wait`	`MPI_Waitall`	`MPI_Waitany`
`MPI_Waitsome`	`MPI_Win_complete`	`MPI_Win_create`
`MPI_Win_fence`	`MPI_Win_free`	`MPI_Win_lock`
`MPI_Win_post`	`MPI_Win_start`	`MPI_Win_test`
`MPI_Win_unlock`		

MPI tracing data is converted into the following metrics.

TABLE 5 MPI Tracing Metrics

Metric	Definition
MPI Sends	Number of MPI point-to-point sends started
MPI Bytes Sent	Number of bytes in MPI Sends
MPI Receives	Number of MPI point - to - point receives completed
MPI Bytes Received	Number of bytes in MPI Receives
MPI Time	Time spent in all calls to MPI functions
Other MPI Events	Number of calls to MPI functions that neither send nor receive point-to-point messages

MPI Time is the total thread time spent in the MPI function. If MPI state times are also collected, MPI Work Time plus MPI Wait Time for all MPI functions other than MPI_Init and MPI_Finalize should approximately equal MPI Work Time. On Linux, MPI Wait and Work are based on user+system CPU time, while MPI Time is based on real time, so the numbers will not match.

MPI byte and message counts are currently collected only for point - to - point messages. They are not recorded for collective communication functions. The MPI Bytes Received metric counts the actual number of bytes received in all messages. MPI Bytes Sent counts the actual number of bytes sent in all messages. MPI Sends counts the number of messages sent, and MPI Receives counts the number of messages received.

Collecting MPI tracing data can help you identify places where you have a performance problem in an MPI program that could be due to MPI calls. Examples of possible performance problems are load balancing, synchronization delays, and communications bottlenecks.

How Metrics Are Assigned to Program Structure

Metrics are assigned to program instructions using the call stack that is recorded with the event-specific data. If the information is available, each instruction is mapped to a line of source code and the metrics assigned to that instruction are also assigned to the line of source code. See Chapter 6, "Understanding Performance Analyzer and Its Data" for a more detailed explanation of how this is done.

In addition to source code and instructions, metrics are assigned to higher - level objects: functions and load objects. The call stack contains information on the sequence of function calls made to arrive at the instruction address recorded when a profile was taken. Performance Analyzer uses the call stack to compute metrics for each function in the program. These metrics are called function-level metrics.

Function-Level Metrics: Exclusive, Inclusive, Attributed, and Static

Performance Analyzer computes three types of function-level metrics: exclusive metrics, inclusive metrics and attributed metrics.

- **Exclusive metrics** for a function are calculated from events which occur inside the function itself: they exclude metrics coming from its calls to other functions.
- **Inclusive metrics** are calculated from events which occur inside the function and any functions it calls: they include metrics coming from its calls to other functions.
- **Attributed metrics** tell you how much of an inclusive metric came from calls from or to another function: they attribute metrics to another function.
- **Static Metrics** are based on the static properties of the load objects in the experiments.

For a function that only appears at the bottom of call stacks (a leaf function), the exclusive and inclusive metrics are the same.

Exclusive and inclusive metrics are also computed for load objects. Exclusive metrics for a load object are calculated by summing the function-level metrics over all functions in the load object. Inclusive metrics for load objects are calculated in the same way as for functions.

Exclusive and inclusive metrics for a function give information about all recorded paths through the function. Attributed metrics give information about particular paths through a function. They show how much of a metric came from a particular function call. The two functions involved in the call are described as a *caller* and a *callee*. For each function in the call tree:

- The attributed metrics for a function's callers tell you how much of the function's inclusive metric was due to calls from each caller. The attributed metrics for the callers sum to the function's inclusive metric.
- The attributed metrics for a function's callees tell you how much of the function's inclusive metric came from calls to each callee. Their sum plus the function's exclusive metric equals the function's inclusive metric.

The relationship between the metrics can be expressed by the following equation:

$$\sum_{\text{callers}} \begin{matrix}\text{Attributed}\\ \text{metric}\end{matrix} = \begin{matrix}\text{Inclusive}\\ \text{metric}\end{matrix} = \left(\sum_{\text{callees}} \begin{matrix}\text{Attributed}\\ \text{metric}\end{matrix} + \begin{matrix}\text{Exclusive}\\ \text{metric}\end{matrix} \right)$$

Comparison of attributed and inclusive metrics for the caller or the callee gives further information:

- The difference between a caller's attributed metric and its inclusive metric tells you how much of the metric came from calls to other functions and from work in the caller itself.
- The difference between a callee's attributed metric and its inclusive metric tells you how much of the callee's inclusive metric came from calls to it from other functions.

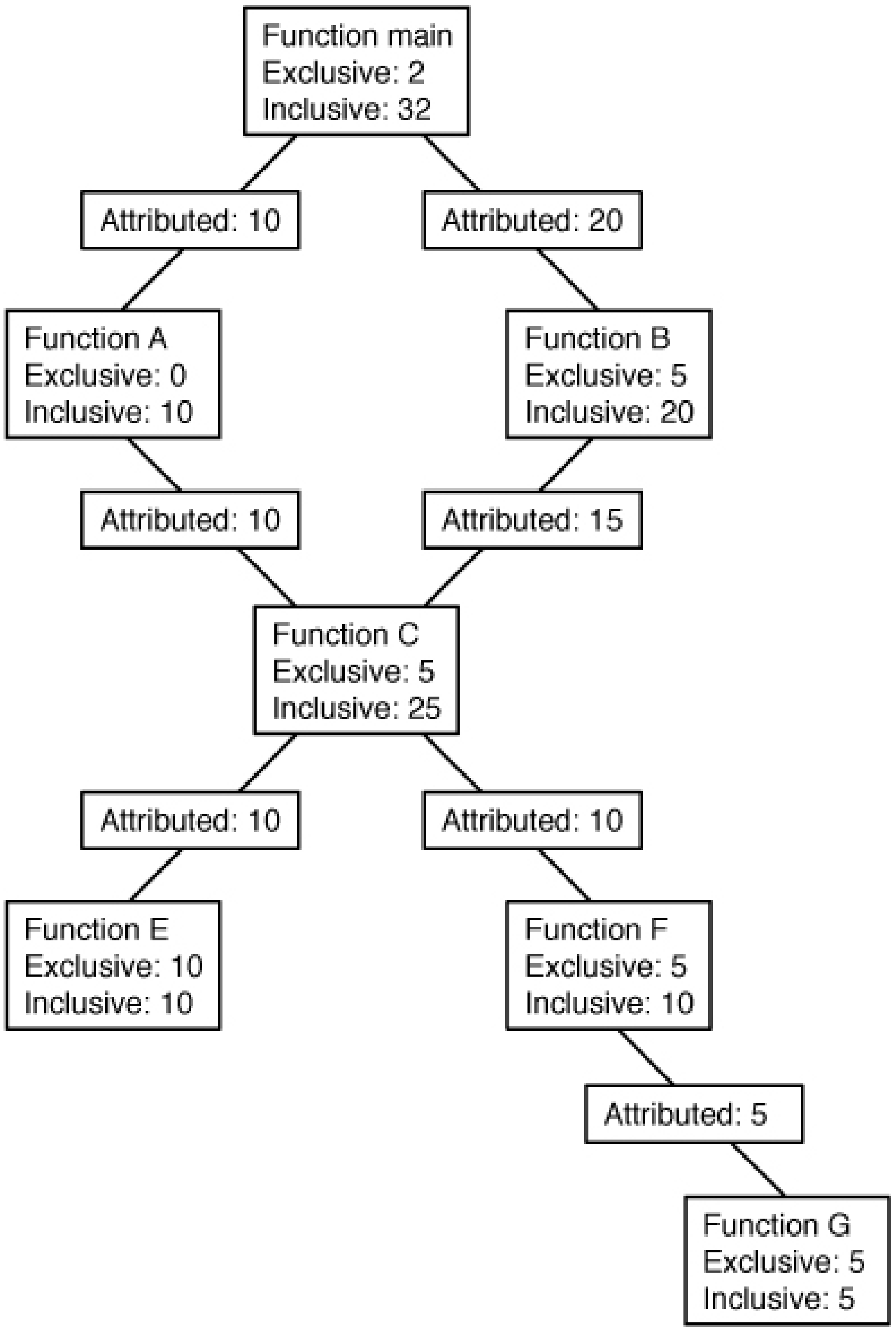
To locate places where you could improve the performance of your program:

- Use exclusive metrics to locate functions that have high metric values.
- Use inclusive metrics to determine which call sequence in your program was responsible for high metric values.
- Use attributed metrics to trace a particular call sequence to the function or functions that are responsible for high metric values.

Interpreting Attributed Metrics: An Example

Exclusive, inclusive and attributed metrics are illustrated in Figure 1, “Call Tree Illustrating Exclusive, Inclusive, and Attributed Metrics,” on page 41, which contains a complete call tree. The focus is on the central function, function C.

Pseudo-code of the program is shown after the diagram.


Function main
Exclusive: 2
Inclusive: 32
Attributed: 10
Attributed: 20
Function A
Exclusive: 0
Inclusive: 10
Function B
Exclusive: 5
Inclusive: 20
Attributed: 10
Attributed: 15
Function C
Exclusive: 5
Inclusive: 25
Attributed: 10
Attributed: 10
Function E
Exclusive: 10
Inclusive: 10
Function F
Exclusive: 5
Inclusive: 10
Attributed: 5
Function G
Exclusive: 5
Inclusive: 5

The Main function calls Function A and Function B, and attributes 10 units of its inclusive metric to Function A and 20 units to function B. These are the callee attributed metrics for function Main. Their sum (10+20) added to the exclusive metric of function Main equals the inclusive metric of function main (32).

Function A spends all of its time in the call to function C, so it has 0 units of exclusive metrics.

Function C is called by two functions: function A and function B, and attributes 10 units of its inclusive metric to function A and 15 units to function B. These are the caller attributed metrics. Their sum (10+15) equals the inclusive metric of function C (25)

The caller attributed metric is equal to the difference between the inclusive and exclusive metrics for function A and B, which means they each call only function C. (In fact, the functions might call other functions but the time is so small that it does not appear in the experiment.)

Function C calls two functions, function E and function F, and attributes 10 units of its inclusive metric to function E and 10 units to function F. These are the callee attributed metrics. Their sum (10+10) added to the exclusive metric of function C (5) equals the inclusive metric of function C (25).

The callee attributed metric and the callee inclusive metric are the same for function E and for function F. This means that both function E and function F are only called by function C. The exclusive metric and the inclusive metric are the same for function E but different for function F. This is because function F calls another function, Function G, but function E does not.

Pseudo-code for this program is shown below.

```
main() {
   A();
   /Do 2 units of work;/
   B();
}

A() {
   C(10);
}

B() {
   C(7.5);
   /Do 5 units of work;/
   C(7.5);
}

C(arg) {
      /Do a total of "arg" units of work, with 20% done in C itself,
      40% done by calling E, and 40% done by calling F./
```

```
    }
```

How Recursion Affects Function-Level Metrics

Recursive function calls, whether direct or indirect, complicate the calculation of metrics. Performance Analyzer displays metrics for a function as a whole, not for each invocation of a function: the metrics for a series of recursive calls must therefore be compressed into a single metric. This behavior does not affect exclusive metrics, which are calculated from the function at the bottom of the call stack (the leaf function), but it does affect inclusive and attributed metrics.

Inclusive metrics are computed by adding the metric for the event to the inclusive metric of the functions in the call stack. To ensure that the metric is not counted multiple times in a recursive call stack, the metric for the event is added only once to the inclusive metric for each unique function.

Attributed metrics are computed from inclusive metrics. In the simplest case of recursion, a recursive function has two callers: itself and another function (the initiating function). If all the work is done in the final call, the inclusive metric for the recursive function is attributed to itself and not to the initiating function. This attribution occurs because the inclusive metric for all the higher invocations of the recursive function is regarded as zero to avoid multiple counting of the metric. The initiating function, however, correctly attributes to the recursive function as a callee the portion of its inclusive metric due to the recursive call.

Static Metric Information

Static metrics are based on fixed properties of load objects. There are three static metrics available for use in commands that accept *metric_spec* in the `er_print` command: `name`, `size` and `address`. Two metrics are in several views of the Performance Analyzer GUI, `size` and `address`.

name	Describes the output name's column in the `er_print` command. For example, if using the `functions` command within `er_print`, name is the column listing function names. See Example 1, “`er_print` and Static Metric Example for Functions,” on page 44.
size	Describes the number of instruction bytes. When looking at PCs or Disassembly information, the size metric shows the width of each instruction in bytes. If looking at Functions

	information, the size metric shows the number of bytes in the object file used to store the function's instructions.
address or PC Address	Describes the offset of the function or instruction within an object file. The address is in the form *NNN*:0x*YYYY*, where *NNN* is the internal number for the object file and *YYYY* is the offset within that object file.

EXAMPLE 1 `er_print` and Static Metric Example for Functions

The following example enables the name, address, and size metrics:

```
-metrics name:address:size
Name        PC Addr.       Size
 <Total>     1:0x00000000    0
 UDiv       15:0x0009a140  296
...
```

For more information about static metrics, see "Static Metrics Example for Functions" in er_print (1) and the "Exclusive, Inclusive, Attributed, and Static Metrics" page in the Help menu of Performance Analyzer.

♦ ♦ ♦ CHAPTER 3

Collecting Performance Data

The first stage of performance analysis is data collection. This chapter describes what is required for data collection, where the data is stored, how to collect data, and how to manage the data collection. For more information about the data itself, see Chapter 2, “Performance Data”.

Data collection is performed from the command line or from the Performance Analyzer tool.

Collecting data at the command line from the kernel requires a separate tool, `er_kernel`. See Chapter 9, “Kernel Profiling” for more information.

This chapter covers the following topics.

Compiling and Linking Your Program

You can collect and analyze data for a program compiled with almost any compiler option, but some choices affect what you can collect or what you can see in Performance Analyzer.

The issues to consider when you compile and link your program are described in the following subsections.

Compiling to Analyze Source Code

To see source code in annotated Source and Disassembly views, and source lines in the Lines view, you must compile the source files of interest with the `-g` compiler option (`-g0` for C++ to enable front-end inlining) to generate debug symbol information. The format of the debug symbol information is DWARF2. specified by `-xdebugformat=dwarf` . This the default.

Executables and libraries built with DWARF format debugging symbols automatically include a copy of each constituent object file's debugging symbols. Executables and libraries built with `stabs` format debugging symbols also include a copy of each constituent object file's debugging symbols if they are linked with the `-xs` option, which leaves `stabs` symbols in the various object files as well as the executable. The inclusion of this information is particularly useful if you need to move or remove the object files. With all of the debugging symbols in the executables and libraries themselves, moving the experiment and the program-related files to a new location is easier.

Programs can be compiled with the Oracle Developer Studio compilers or GNU compilers. However, GNU compilers cannot support some features such as reconstructed call stacks with OpenMP.

Compiling with `-g` does not change optimization, except for tail call optimization at the `O2` and `O3` optimization levels in Oracle Developer Studio compilers.

Source level information for Java code is supported. The location of Java sources, unlike that for native languages, is not recorded in the experiments. You might need to use path mapping or set the search path to point to your source. See "How the Tools Find Source Code" on page 231 for more information.

Compiling for Dataspace and Memoryspace Profiling

Dataspace profiling attributes memory access to data structure elements. To enable dataspace profiling, you must compile C, C++, and Fortran executables with the Oracle Developer Studio compilers and the `-xhwcprof` option. If you do not compile with this option, the DataObjects and DataLayout views do not show data for the binaries.

Memoryspace profiling enables you to see which memory addresses are costing the most performance. No special compiler options are necessary to prepare a program for memoryspace profiling, but the feature is available only on SPARC platforms running Oracle Solaris 10or later, and on Intel platforms running Oracle Solaris 11.2 or later. See "Dataspace Profiling and Memoryspace Profiling" on page 201 for more information.

Static Linking

For some types of performance data such as heap tracing and I/O tracing, data collection relies on a dynamically linked `libc`. This functionality is lost when you link statically, so you should not use options such as `-dn` and `-Bstatic` to control `libc`with Oracle Developer Studio compilers.

If you try to collect data for a program that is entirely statically linked, the Collector prints an error message and does not collect data. The error occurs because the collector library, among others, is dynamically loaded when you run the Collector.

Do not statically link any of the system libraries or the Collector library, `libcollector.so`.

Shared Object Handling

Normally the `collect` command causes data to be collected for all shared objects in the address space of the target, regardless of whether they are on the initial library list or are explicitly loaded with `dlopen()`. However, under some circumstances some shared objects are not profiled:

- When the target program is invoked with lazy loading. In such cases, the library is not loaded at start-up time, and is not loaded by explicitly calling `dlopen()`, so shared object might not be not included in the experiment, and all PCs from it are mapped to the `<Unknown>` function. The workaround is to set the `LD_BIND_NOW` environment variable, which forces the library to be loaded at start-up time.
- When the executable was built with the `-B direct` option. In this case, the object is dynamically loaded by a call specifically to the dynamic linker entry point of `dlopen()`, and the `libcollector` interposition is bypassed. The shared object name might not be included in the experiment, and all PCs from it are mapped to the `<Unknown>()` function. The workaround is to not use the `-B direct` option. If the program terminates normally, such shared objects are detected and recorded.

Optimization at Compile Time

If you compile your program with optimization turned on at some level, the compiler can rearrange the order of execution so that it does not strictly follow the sequence of lines in your program. Performance Analyzer can analyze experiments collected on optimized code, but the data it presents at the disassembly level is often difficult to relate to the original source code lines. In addition, the call sequence can appear to be different from what you expect if the compiler performs tail-call optimizations. See "Tail-Call Optimization" on page 206 for more information.

Compiling Java Programs

No special action is required for compiling Java programs with the `javac` command.

Preparing Your Program for Data Collection and Analysis

You do not need to do anything special to prepare most programs for data collection and analysis. You should read one or more of the subsections below if your program does any of the following:

- Installs a signal handler. See "Data Collection and Signals" on page 53.
- Dynamically compiles functions. See "Dynamic Functions and Modules" on page 57.
- Creates descendant processes that you want to profile. See "Follow Processes with the `-F` *option*" on page 80.
- Uses the profiling timer or hardware counter API directly. See "Using System Libraries" on page 50.
- Calls `setuid`(2) or executes a `setuid` file. See "Data Collection and Signals" on page 53 and "Using `setuid` and `setgid`" on page 54.

Also, if you want to control data collection from your program during runtime, see "Program Control of Data Collection Using libcollector Library" on page 55.

Using Dynamically Allocated Memory

Many programs rely on dynamically-allocated memory, using features such as:

- `malloc`, `valloc`, `alloca` (C/C++)
- `new` (C++)
- Stack local variables (Fortran)
- `MALLOC`, `MALLOC64` (Fortran)

You must take care to ensure that a program does not rely on the initial contents of dynamically allocated memory unless the memory allocation method is explicitly documented as setting an initial value. For example, compare the descriptions of `calloc` and `malloc` in the man page for `malloc`(3C).

Occasionally, a program that uses dynamically allocated memory might appear to work correctly when run alone, but might fail when run with performance data collection enabled. Symptoms might include unexpected floating - point behavior, segmentation faults, or application-specific error messages.

Such behavior might occur if the uninitialized memory is, by chance, set to a benign value when the application is run alone but is set to a different value when the application is run in conjunction with the performance data collection tools. In such cases, the performance tools are not at fault. Any application that relies on the contents of dynamically allocated memory has a latent bug: an operating system is at liberty to provide any content whatsoever in dynamically allocated memory unless explicitly documented otherwise. Even if an operating system happens to always set dynamically allocated memory to a certain value today, such latent bugs might cause unexpected behavior with a later revision of the operating system, or if the program is ported to a different operating system in the future.

The following tools may help in finding such latent bugs:

- Code Analyzer, a Oracle Developer Studio tool which when used with the compilers and other tools can show the following:

Static code checking	Code Analyzer can show results of static code checking, which is performed when you compile your application with the Oracle Developer Studio C or C++ compiler and specify the `-xanalyze=code` option.
Dynamic memory access checking	Code Analyzer can show results of dynamic memory access checking, which is performed when you instrument your binary with `discover` using the `-a` option, and then run the instrumented binary to generate data.

  For more information, see *Oracle Developer Studio 12.6: Code Analyzer User's Guide*
- `f95 -xcheck=init_local`

  For more information, see the *Oracle Developer Studio 12.6: Fortran User's Guide* or the `f95`(1) man page.
- `lint` utility

  For more information, see the *Oracle Developer Studio 12.6: C User's Guide* or the `lint`(1) man page.
- Runtime checking under `dbx`

  For more information, see the *Oracle Developer Studio 12.6: Debugging a Program with dbx* manual or the `dbx`(1) man page.

Using System Libraries

The Collector interposes on functions from various system libraries to collect tracing data and to ensure the integrity of data collection. The following list describes situations in which the Collector interposes on calls to library functions.

- Collecting synchronization wait tracing data. The Collector interposes on functions from the Oracle Solaris C library, `libc.so`, on Oracle Solaris.
- Collecting I/O Trace data. The Collector interposes on the following functions:

```
/* interposition function handles */
static int (*__real_open)(const char *path, int oflag, ...) = NULL;
#if WSIZE(32)
static int (*__real_open64)(const char *path, int oflag, ...) = NULL;
#endif
static int (*__real_fcntl)(int fildes, int cmd, ...) = NULL;
static int (*__real_openat)(int fildes, const char *path, int oflag, ...) = NULL;
static int (*__real_close)(int fildes) = NULL;
static FILE *(*__real_fopen)(const char *filename, const char *mode) = NULL;
static int (*__real_fclose)(FILE *stream) = NULL;
static int (*__real_dup)(int fildes) = NULL;
static int (*__real_dup2)(int fildes, int fildes2) = NULL;
static int (*__real_pipe)(int fildes[2]) = NULL;
static int (*__real_socket)(int domain, int type, int protocol) = NULL;
static int (*__real_mkstemp)(char *template) = NULL;
static int (*__real_mkstemps)(char *template, int slen) = NULL;
static int (*__real_creat)(const char *path, mode_t mode) = NULL;

#if WSIZE(32)
static int (*__real_creat64)(const char *path, mode_t mode) = NULL;
#endif
static FILE *(*__real_fdopen)(int fildes, const char *mode) = NULL;

static ssize_t (*__real_read)(int fildes, void *buf, size_t nbyte) = NULL;
static ssize_t (*__real_write)(int fildes, const void *buf, size_t nbyte) = NULL;
static ssize_t (*__real_readv)(int fildes, const struct iovec *iov, int iovcnt) =
 NULL;
static ssize_t (*__real_writev)(int fildes, const struct iovec *iov, int iovcnt) =
 NULL;
static size_t (*__real_fread)(void *ptr, size_t size, size_t nitems, FILE *stream) =
 NULL;
static size_t (*__real_fwrite)(void *ptr, size_t size, size_t nitems, FILE *stream) =
 NULL;
```

```
static ssize_t (*__real_pread)(int fildes, void *buf, size_t nbyte, off_t offset) =
 NULL;
static ssize_t (*__real_pwrite)(int fildes, const void *buf, size_t nbyte, off_t
 offset) = NULL;
#if OS(Linux)
static ssize_t (*__real_pwrite64)(int fildes, const void *buf, size_t nbyte, off64_t
 offset) = NULL;
#endif
static char *(*__real_fgets)(char *s, int n, FILE *stream) = NULL;
static int (*__real_fputs)(const char *s, FILE *stream) = NULL;
static int (*__real_fputc)(int c, FILE *stream) = NULL;
static int (*__real_fprintf)(FILE *stream, const char *format, ...) = NULL;
static int (*__real_vfprintf)(FILE *stream, const char *format, va_list ap) = NULL;

static off_t (*__real_lseek)(int fildes, off_t offset, int whence) = NULL;
static offset_t (*__real_llseek)(int fildes, offset_t offset, int whence) = NULL;
static int (*__real_chmod)(const char *path, mode_t mode) = NULL;
static int (*__real_access)(const char *path, int amode) = NULL;
static int (*__real_rename)(const char *old, const char *new) = NULL;
static int (*__real_mkdir)(const char *path, mode_t mode) = NULL;
static int (*__real_getdents)(int fildes, struct dirent *buf, size_t nbyte) = NULL;
static int (*__real_unlink)(const char *path) = NULL;
static int (*__real_fseek)(FILE *stream, long offset, int whence) = NULL;
static void (*__real_rewind)(FILE *stream) = NULL;
static long (*__real_ftell)(FILE *stream) = NULL;
static int (*__real_fgetpos)(FILE *stream, fpos_t *pos) = NULL;
static int (*__real_fsetpos)(FILE *stream, const fpos_t *pos) = NULL;
#if WSIZE(32)
static int (*__real_fgetpos64)(FILE *stream, fpos64_t *pos) = NULL;
static int (*__real_fsetpos64)(FILE *stream, const fpos64_t *pos) = NULL;
#endif // WSIZE(32)
static int (*__real_fsync)(int fildes) = NULL;
static struct dirent *(*__real_readdir)(DIR *dirp) = NULL;
#if OS(Linux)
static int (*__real_flock)(int fd, int operation) = NULL;
#endif
static int (*__real_lockf)(int fildes, int function, off_t size) = NULL;
static int (*__real_fflush)(FILE *stream) = NULL;
#if OS(Linux) && ARCH(Intel) && WSIZE(32)
static FILE *(*__real_fopen_2_1)(const char *filename, const char *mode) = NULL;
static int (*__real_fclose_2_1)(FILE *stream) = NULL;
static FILE *(*__real_fdopen_2_1)(int fildes, const char *mode) = NULL;
static int (*__real_fgetpos_2_2)(FILE *stream, fpos_t *pos) = NULL;
static int (*__real_fsetpos_2_2)(FILE *stream, const fpos_t *pos) = NULL;
static FILE *(*__real_fopen_2_0)(const char *filename, const char *mode) = NULL;
static int (*__real_fclose_2_0)(FILE *stream) = NULL;
static FILE *(*__real_fdopen_2_0)(int fildes, const char *mode) = NULL;
static int (*__real_fgetpos_2_0)(FILE *stream, fpos_t *pos) = NULL;
static int (*__real_fsetpos_2_0)(FILE *stream, const fpos_t *pos) = NULL;
#endif
```

- Collecting heap tracing data. The Collector interposes on the functions `malloc`, `realloc`, `memalign` and `free`. Versions of these functions are found in the C standard library, `libc.so`, and also in other libraries such as `libumen.so`, `libmalloc.so`, and `libmtmalloc.so`.
- Collecting MPI tracing data. The Collector interposes on functions from the specified MPI library.
- Ensuring the integrity of clock data. The Collector interposes on `setitimer` and prevents the program from using the profiling timer.
- Ensuring the integrity of hardware counter data. The Collector interposes on functions from the hardware counter library, `libcpc.so`, and prevents the program from using the counters. Calls from the program to functions from this library return a value of `-1`.
- Enabling data collection on descendant processes. The Collector interposes on the functions `fork`(2), `fork1`(2), `vfork`(2), `fork`(3F), `posix_spawn`(3p), `posix_spawnp`(3p), `system`(3C), `system`(3F), `sh`(3F), `popen`(3C), and `exec`(2) and its variants. Calls to `vfork` are replaced internally by calls to `fork1`. These interpositions are done for the `collect` command.
- Guaranteeing the handling of the `SIGPROF` and `SIGEMT` signals by the Collector. The Collector interposes on `sigaction` to ensure that its signal handler is the primary signal handler for these signals.

The interposition does not succeed under the following circumstances:

- Statically linking a program with any of the libraries that contain functions that are interposed.
- Attaching `dbx` to a running application that does not have the collector library preloaded.
- Dynamically loading one of these libraries and resolving the symbols by searching only within the library.

The failure of interposition by the Collector can cause loss or invalidation of performance data.

The `er_sync.so`, `er_iotrace.so`, `er_heap.so`, and `er_mpviewn.so` (where *n* indicates the MPI version) libraries are loaded only if synchronization wait tracing data, I/O tracing data, heap tracing data, or MPI tracing data, respectively, are requested.

Data Collection and Signals

Signals are used for both clock profiling and hardware counter profiling. `SIGPROF` is used in data collection for all experiments. The period for generating the signal depends on the data being collected. `SIGEMT` on Solaris or `SIGIO` on Linux is used for hardware counter profiling. The overflow interval depends on the user parameter for profiling. Any user code that uses or manipulates the profiling signals may potentially interfere with data collection. When the Collector installs its signal handler for a profile signal, it sets a flag that ensures that system calls are not interrupted to deliver signals. This setting could change the behavior of a target program that uses the profiling signals for other purposes.

When the Collector installs its signal handler for a profile signal, it remembers whether or not the target had installed its own signal handler. The Collector also interposes on some signal-handling routines and does not allow the user to install a signal handler for these signals; it saves the user's handler, just as it does when the Collector replaces a user handler on starting the experiment.

Profiling signals are delivered by from the profiling timer or hardware-counter-overflow handling code in the kernel, or in response to: the `kill(2), sigsend(2) tkill(2), tgkill(2)` or `_lwp_kill(2)` system calls, the `raise(3C)` and `sigqueue(3C)` library calls or the `kill` command. A signal code is delivered with the signal so that the Collector can distinguish the origin. If it is delivered for profiling, it is processed by the Collector; if it is not delivered for profiling, it is delivered to the target signal handler.

When the Collector is running under `dbx`, the profiling signal delivered occasionally has its signal code corrupted, and a profile signal may be treated as if it were generated from a system or library call or a command. In that case, it will be incorrectly delivered to the user's handler. If the user handler was set to `SIG_DFL`, it will cause the process to fail core dump.

When the Collector is invoked after attaching to a target process, it will install its signal handler, but it cannot interpose on the signal-handling routines. If those user code installs a signal handler after the attach, it will override the Collector's signal handler, and data will be lost.

Note that any signal including either of the profiling signals might cause premature termination of a system call. The program must be prepared to handle that behavior. When `libcollector` installs the signal handlers for data collection it specifies to restart system calls that can be restarted. However, some system calls such as `sleep`(3C) return early without reporting an error.

Sample and Pause-Resume Signals

Signals may be specified by the user as a sample signal (-l) or a pause-resume signal (-y). SIGUSR1 or SIGUSR2 are recommended for this use, but any signal that is not used by the target, may be used.

The profiling signals may be used if the process does not otherwise use them, but they should be used only if no other signal is available. The Collector interposes on some signal-handling routines and does not allow the user to install a signal handler for these signals; it saves the user's handler, just as it does when the Collector replaces a user handler on starting the experiment.

If the Collector is invoked after attaching to a target process, and the user code installs a signal handler for the sample or pause-resume signal, those signals will not longer operate as specified.

Using `setuid` and `setgid`

Restrictions enforced by the dynamic loader make it difficult to use `setuid`(2) and collect performance data. If your program calls `setuid` or executes a `setuid` file, the Collector probably cannot write an experiment file because it lacks the necessary permissions for the new user ID.

The `collect` command operates by inserting a shared library, `libcollector.so`, into the target's address space (`LD_PRELOAD`). Several problems might arise if you invoke the `collect` command invoked on executables that call `setuid` or `setgid`, or that create descendant processes that call `setuid` or `setgid`. If you are not root when you run an experiment, collection fails because the shared libraries are not installed in a trusted directory. The workaround is to run the experiments as root, or use `crle(1)` to grant permission. Take great care when circumventing security barriers; you do so at your own risk.

When running the `collect` command, your `umask` must be set to allow write permission for you, for any users or groups that are set by the `setuid` attributes and `setgid` attributes of a program being executed with `exec()`, and for any user or group to which that program sets itself. If the mask is not set properly, some files might not be written to the experiment, and processing of the experiment might not be possible. If the log file can be written, an error is shown when you attempt to process the experiment.

Other problems can arise if the target itself makes any of the system calls to set UID or GID, or if it changes its `umask` and then forks or runs `exec()` on some other executable, or if `crle` was used to configure how the runtime linker searches for shared objects.

If an experiment is started as root on a target that changes its effective GID, the `er_archive` process that is automatically run when the experiment terminates fails because it needs a shared library that is not marked as trusted. In that case, you can run the `er_archive` utility (or the `er_print` utility or the `analyzer` command) immediately following the termination of the experiment, on the machine on which the experiment was recorded.

Program Control of Data Collection Using libcollector Library

If you want to control data collection from your program, the Collector shared library, `libcollector.so` contains some API functions that you can use. The functions are written in C. A Fortran interface is also provided. Both C and Fortran interfaces are defined in header files that are provided with the library.

The API functions are defined as follows.

```
void collector_sample(char *name);
void collector_pause(void);
void collector_resume(void);
void collector_terminate_expt(void);
```

Similar functionality is provided for Java™ programs by the `CollectorAPI` class, which is described in "Java Interface" on page 56.

C and C++ Interface

You can access the C and C++ interface of the Collector API by including `collectorAPI.h` and linking with `-lcollectorAPI`, which contains real functions to check for the existence of the underlying `libcollector.so` API functions.

If no experiment is active, the API calls are ignored.

Fortran Interface

The Fortran API `libfcollector.h` file defines the Fortran interface to the library. The application must be linked with `-lcollectorAPI` to use this library. (An alternate name for the library, `-lfcollector`, is provided for backward compatibility.) The Fortran API provides the same features as the C and C++ API, excluding the dynamic function and thread pause and resume calls.

Insert the following statement to use the API functions for Fortran:

```
include "libfcollector.h"
```

Note - Do not link a program in any language with `-lcollector`. If you do, the Collector might exhibit unpredictable behavior.

Java Interface

Use the following statement to import the `CollectorAPI` class and access the Java API. Note however that your application must be invoked with a classpath pointing to `/`*installation_directory*`/lib/collector.jar` where *installation-directory* is the directory in which the Oracle Developer Studio software is installed.

```
import com.sun.forte.st.collector.CollectorAPI;
```

The Java `CollectorAPI` methods are defined as follows:

```
CollectorAPI.sample(String name)
CollectorAPI.pause()
CollectorAPI.resume()
CollectorAPI.terminate()
```

The Java API includes the same functions as the C and C++ API, excluding the dynamic function API.

The C include file `libcollector.h` contains macros that bypass the calls to the real API functions if data is not being collected. In this case, the functions are not dynamically loaded. However, using these macros is risky because the macros do not work well under some circumstances. Using `collectorAPI.h` is safer because it does not use macros. Rather, it refers directly to the functions.

The Fortran API subroutines call the C API functions if performance data is being collected, otherwise, they return. The overhead for the checking is very small and should not significantly affect program performance.

To collect performance data you must run your program using the Collector, as described later in this chapter. Inserting calls to the API functions does not enable data collection.

If you intend to use the API functions in a multithreaded program, ensure that they are called only by one thread. The API functions perform actions that apply to the process and not to individual threads. If each thread calls the API functions, the data that is recorded might not be what you expect. For example, if `collector_pause()` or `collector_terminate_expt()` is called by one thread before the other threads have reached the same point in the program, collection is paused or terminated for all threads, and data can be lost from the threads that were executing code before the API call.

C, C++, Fortran, and Java API Functions

This section provides descriptions of the API functions.

- **C and C++**: `collector_sample(char *name)`

  Fortran: `collector_sample(string name)`

  Java: `CollectorAPI.sample(String name)`

  Record a sample packet and label the sample with the given name or string. The label is displayed by Performance Analyzer in the Selection Details window when you select a sample in the Timeline view. The Fortran argument `string` is of type `character`.

  Sample points contain data for the process and not for individual threads. In a multithreaded application, the `collector_sample()` API function ensures that only one sample is written if another call is made while it is recording a sample. The number of samples recorded can be less than the number of threads making the call.

  Performance Analyzer does not distinguish between samples recorded by different mechanisms. If you want to see only the samples recorded by API calls, you should turn off all other sampling modes when you record performance data.
- **C, C++, Fortran**: `collector_pause()`

  Java: `CollectorAPI.pause()`

  Stop writing event-specific data to the experiment. The experiment remains open, and global data continues to be written. The call is ignored if no experiment is active or if data recording is already stopped. This function stops the writing of all event-specific data even if it is enabled for specific threads by the `collector_thread_resume()` function.
- **C, C++, Fortran**: `collector_resume()`

  Java: `CollectorAPI.resume()`

  Resume writing event-specific data to the experiment after a call to `collector_pause()` . The call is ignored if no experiment is active or if data recording is active.
- **C, C++, Fortran**: `collector_terminate_expt()`

  Java: `CollectorAPI.terminate`

  Terminate the experiment whose data is being collected. No further data is collected, but the program continues to run normally. The call is ignored if no experiment is active.

Dynamic Functions and Modules

If your C or C++ program dynamically compiles functions into the data space of the program, you must supply information to the Collector if you want to see data for the dynamic function or module in Performance Analyzer. The information is passed by calls to collector API functions. The definitions of the API functions are as follows.

```
void collector_func_load(char *name, char *alias,
    char *sourcename, void *vaddr, int size, int lntsize,
    Lineno *lntable);
void collector_func_unload(void *vaddr);
```

You do not need to use these API functions for Java methods that are compiled by the Java HotSpot™ virtual machine, for which a different interface is used. The Java interface provides the name of the method that was compiled to the Collector. You can see function data and annotated disassembly listings for Java compiled methods, but not annotated source listings.

This section provides descriptions of the API functions.

`collector_func_load()` Function

Pass information about dynamically compiled functions to the Collector for recording in the experiment. The parameter list is described in the following table.

TABLE 6 Parameter List for `collector_func_load()`

Parameter	Definition
`name`	The name of the dynamically compiled function that is used by the performance tools. The name does not have to be the actual name of the function. The name need not follow any of the normal naming conventions of functions, although it should not contain embedded blanks or embedded quote characters.
`alias`	An arbitrary string used to describe the function. It can be `NULL`. It is not interpreted in any way, and can contain embedded blanks. It is displayed in the Summary tab of the Analyzer. It can be used to indicate what the function is, or why the function was dynamically constructed.
`sourcename`	The path to the source file from which the function was constructed. It can be `NULL`. The source file is used for annotated source listings.
`vaddr`	The address at which the function was loaded.
`size`	The size of the function in bytes.
`lntsize`	A count of the number of entries in the line number table. It should be zero if line number information is not provided.
`lntable`	A table containing `lntsize` entries, each of which is a pair of integers. The first integer is an offset, and the second entry is a line number. All instructions between an offset in one entry and the offset given in the next entry are attributed to the line number given in the first entry. Offsets must be in increasing numeric order, but the order of line numbers is arbitrary. If `lntable` is `NULL`, no source listings of the function are possible, although disassembly listings are available.

`collector_func_unload()` Function

Inform the collector that the dynamic function at the address `vaddr` has been unloaded.

Limitations on Data Collection

This section describes the limitations on data collection that are imposed by the hardware, the operating system, the way you run your program, or by the Collector itself.

There are no limitations on simultaneous collection of different data types. You can collect any data type with any other data type, with the exception of count data.

By default, the Collector collects stacks that are, at most, up to 256 frames deep. If the stack is deeper, you might see the `<Truncated-stack>` function in `er_print` and Performance Analyzer. See "`<Truncated-stack>` Function" on page 224 for more information. To support deeper stacks, set the `SP_COLLECTOR_STACKBUFSZ` environment variable to a larger number.

Limitations on Clock Profiling

The minimum value of the profiling interval and the resolution of the clock used for profiling depend on the particular operating environment. The maximum value is set to 1 second. The value of the profiling interval is rounded down to the nearest multiple of the clock resolution. To display the minimum and maximum value and the clock resolution, type the `collect` command with no additional arguments.

You cannot do clock profiling on a program that uses the profiling timer. The Collector intercepts calls to `setitimer`(3) that set the profiling clock parameters and prevents other programs from using them.

On Linux platforms, the clock data can only be shown as Total CPU time. Linux CPU time is the sum of user CPU time and system CPU time.

On Linux systems, clock-profiling of multithreaded applications might report inaccurate data for threads. The profile signal is not always delivered by the kernel to each thread at the specified interval; sometimes the signal is delivered to the wrong thread. If available, hardware counter profiling using the cycle counter will usually give more accurate data for threads.

Runtime Distortion and Dilation With Clock Profiling

Clock profiling records data when a `SIGPROF` signal is delivered to the target. It causes dilation to process that signal, and unwind the call stack. The deeper the call stack and the more frequent the signals, the greater the dilation. To a limited extent, clock profiling shows some distortion, deriving from greater dilation for those parts of the program executing with the deepest stacks.

Where possible, a default value is set not to an exact number of milliseconds, but to slightly more or less than an exact number (for example, 10.007 ms or 0.997 ms) to avoid correlations with the system clock, which can also distort the data. Set custom values the same way on Oracle Solaris platforms (not possible on Linux platforms).

Limitations on Collection of Tracing Data

You cannot collect any kind of tracing data from a program that is already running unless the Collector library, `libcollector.so`, had been preloaded. See "Collecting Tracing Data From a Running Program" on page 97 for more information.

Runtime Distortion and Dilation With Tracing

Tracing data dilates the run in proportion to the number of events that are traced. If done with clock profiling, the clock data is distorted by the dilation induced by tracing events.

Limitations on Hardware Counter Profiling

Hardware counter profiling has several limitations:

- You can only collect hardware counter data on processors that have hardware counters and that support hardware counter profiling. On other systems, hardware counter profiling is disabled. Oracle Solaris and Oracle Linux with Unbreakable Enterprise Kernel or Red Hat-compatible kernel 6.0 and newer do support hardware counters.
- You cannot collect hardware counter data on a system running Oracle Solaris while the `cpustat`(1) command is running because `cpustat` takes control of the counters and does not let a user process use the counters. If `cpustat` is started during data collection, the hardware counter profiling is terminated and an error is recorded in the experiment. The same is true if `root` starts an `er_kernel` experiment using hardware counters.

- You cannot use the hardware counters in your own code if you are doing hardware counter profiling. The Collector interposes on the `libcpc` library functions and returns with a return value of `-1` if the call did not come from the Collector. Your program should be coded so as to work correctly if it fails to get access to the hardware counters. If not coded to handle this, the program will fail under hardware counter profiling, or if the superuser invokes system-wide tools that also use the counters, or if the counters are not supported on that system.
- If you try to collect hardware counter data on a running program that is using the hardware counter library by attaching `dbx` to the process, the experiment might be corrupted or the program might fail.

Note - To view a list of all available counters, run the `collect -h` command with no additional arguments.

Runtime Distortion and Dilation With Hardware Counter Profiling

Hardware counter profiling records data when a `SIGEMT` signal (on Oracle Solaris platforms) or a `SIGIO` signal (on Linux platforms) is delivered to the target. It causes dilation to process that signal and unwind the call stack. Unlike clock profiling, for some hardware counters, different parts of the program might generate events more rapidly than other parts and show dilation in that part of the code. Any part of the program that generates such events very rapidly might be significantly distorted. Similarly, some events might be generated in one thread disproportionately to the other threads.

Limitations on Data Collection for Descendant Processes

You can collect data on descendant processes subject to some limitations.

If you want to collect data for all descendant processes that are followed by the Collector, you must use the `collect` command with one of the following options:

- `-F on` option enables you to collect data automatically for calls to `fork` and its variants and `exec` and its variants, and all other descendant processes, including those due to calls to `system`, `popen`, `posix_spawn`(3p), `posix_spawnp`(3p), and `sh`
- `-F all` is the same as `-F on`.

- `-F` '=*regexp*' option enables data to be collected on all descendant processes whose name matches the specified regular expression.

See "Experiment Control Options" on page 79 for more information about the `-F` option.

Limitations on OpenMP Profiling

Collecting OpenMP data during the execution of the program can be very expensive. You can suppress that cost by setting the `SP_COLLECTOR_NO_OMP` environment variable. If you do so, the program will have substantially less dilation, but you will not see the data from slave threads propagate up to the caller, and eventually to `main()`, as it normally will if that variable is not set.

OpenMP profiling functionality is available only for applications compiled with the Oracle Developer Studio compilers because it depends on the Oracle Developer Studio compiler runtime. For applications compiled with GNU compilers, only machine-level call stacks are displayed.

Limitations on Java Profiling

You can collect data on Java programs subject to the following limitations:

- You should use a version of the Java 2 Software Development Kit (JDK) no earlier than JDK 7, Update 25 (JDK 1.7.0_25). The Collector first looks for the JDK in the path set in either the `JDK_HOME` environment variable or the `JAVA_PATH` environment variable. If neither of these variables is set, it looks for a JDK in your `PATH`. If there is no JDK in your `PATH`, it looks for the `java` executable in `/usr/java/bin/java`.

  The Collector verifies that the version of the `java` executable it finds is an ELF executable. If it is not, an error message is printed indicating which environment variable or path was used and the full path name that was tried.
- You must use the `collect` command to collect data. You cannot use the `dbx collector` subcommands.
- Some applications are not pure Java, but are C or C++ applications that invoke `dlopen()` to load `libjvm.so`, and then start the JVM software by calling into it. To profile such applications, set the `SP_COLLECTOR_USE_JAVA_OPTIONS` environment variable. Do not set the `LD_LIBRARY_PATH` environment variable for this scenario.

Runtime Performance Distortion and Dilation for Applications Written in the Java Programming Language

Java profiling uses the Java Virtual Machine Tools Interface (JVMTI), which can cause some distortion and dilation of the run.

For clock profiling and hardware counter profiling, the data collection process makes various calls into the JVM software and handles profiling events in signal handlers. The overhead of these routines and the cost of writing the experiments to disk will dilate the runtime of the Java program. Such dilation is typically less than 10%.

Where the Data Is Stored

The data collected during one execution of your application is called an *experiment*. The experiment consists of a set of files that are stored in a directory. The name of the experiment is the name of the directory.

In addition to recording the experiment data, the Collector creates its own archives of the load objects used by the program. These archives contain the addresses, sizes, and names of each object file and each function in the load object, as well as the address of the load object and a timestamp for its last modification. Archives might also have copies of all shared objects and some or all of the source files. See "`er_archive` Utility" on page 259 for more information on archiving and "Function-Level Metrics: Exclusive, Inclusive, Attributed, and Static" on page 39 for more information about addresses, sizes, and names..

Experiments are stored by default in the current directory. If this directory is on a networked file system, storing the data takes longer than on a local file system and can distort the performance data. You should always try to record experiments on a local file system if possible. You can specify the storage location when you run the Collector.

Experiments for descendant processes are stored inside the experiment for the founder process.

Experiment Names

The default name for a new experiment is `test.1.er` . The suffix `.er` is mandatory: if you provide a name without this suffix, an error message is displayed and the name is not accepted.

If you choose a name with the format *experiment*`.`*n*`.er`, where *n* is a positive integer, the Collector automatically increments *n* by one in the names of subsequent experiments. For example, `mytest.1.er` is followed by `mytest.2.er`, `mytest.3.er` , and so on. The Collector also increments *n* if the experiment already exists, and continues to increment *n* until it finds an experiment name that is not in use. If the experiment name does not contain *n* and the experiment exists, the Collector prints an error message.

Subexperiments follow similar naming rules. See "Subexperiments" on page 195 for more information.

Experiment Groups

Experiments can be collected into groups. The group is defined in an experiment group file, which is stored by default in the current directory. The experiment group file is a plain text file with a special header line and an experiment name on each subsequent line. The default name for an experiment group file is `test.erg`. If the name does not end in `.erg`, an error is displayed and the name is not accepted. Once you have created an experiment group, any experiments you run with that group name are added to the group.

To manually create an experiment group file, create a plain text file whose first line is as follows:

```
#analyzer experiment group
```

Then add the names of the experiments on subsequent lines. The file extension must be`.erg`.

You can also create an experiment group by using the `-g` argument to the `collect` command.

Experiments for Descendant Processes

Experiments for descendant processes are named with their lineage as follows. To form the experiment name for a descendant process, an underscore, a code letter, and a number are added to the stem of its creator's experiment name. The code letter is `f` for a fork, `x` for an exec, and `c` for combination. The number is the index of the fork or exec (whether successful or not). For example, if the experiment name for the founder process is `test.1.er`, the experiment for the child process created by the third call to `fork` is `test.1.er/_f3.er` . If that child process calls `exec` successfully, the experiment name for the new descendant process is `test.1.er/_f3_x1.er`.

Experiments for MPI Programs

Data for MPI programs are collected by default into `test.1.er`, and all the data from the MPI processes are collected into subexperiments, one per rank. The Collector uses the MPI rank to construct a subexperiment name with the form `M_r`*m*`.er`, where *m* is the MPI rank. For example, MPI rank 1 would have its experiment data recorded in the `test.1.er/M_r1.er` directory.

Experiments on the Kernel and User Processes

Experiments on the kernel by default are named `ktest.1.er` rather than `test.1.er`. When data is also collected on user processes, the kernel experiment contains subexperiments for each user process being followed.

The subexperiments are named using the format *_process-name*`_PID_`*process-id*`.1.er`. For example an experiment run on a `sshd` process running under process ID 1264 would be named `ktest.1.er/_sshd_PID_1264.1.er`.

Moving Experiments

If you want to move an experiment to another computer to analyze it, you should be aware of the dependencies of the analysis on the operating environment in which the experiment was recorded.

The experiment contains all the information necessary to compute metrics at the function level and to display the timeline. However, if you want to see annotated source code or annotated disassembly code, you must have access to versions of the load objects or source files that are identical to the ones used to build the target or the experiment.

See “How the Tools Find Source Code” on page 231 for a description of the process used to find an experiment's source code.

To ensure that you see the correct annotated source code and annotated disassembly code for your program, you can copy the source code, the object files, and the executable into the experiment using the `er_archive` command before you move or copy the experiment.

See the `er_archive`(1) man page for more information.

Estimating Storage Requirements

This section provides some guidelines for estimating the amount of disk space needed to record an experiment. The size of the experiment depends directly on the size of the data packets and the rate at which they are recorded, the number of LWPs used by the program, and the execution time of the program.

The data packets contain event-specific data and data that depends on the program structure (the call stack). The amount of data that depends on the data type is approximately 50 to 100 bytes. The call stack data consists of return addresses for each call, and contains 4 bytes per address, or 8 bytes per address on 64 bit executables. Data packets are recorded for each thread in the experiment. Note that for Java programs, there are two call stacks of interest: the Java call stack and the machine call stack, which therefore result in more data being written to disk.

The rate at which profiling data packets are recorded is controlled by the profiling interval for clock data, the overflow value for hardware counter data, and, for tracing of functions, the rate of occurrences of traced functions. The choice of profiling interval parameters affects the data quality and the distortion of program performance due to the data collection overhead. Smaller values of these parameters give better statistics but also increase the overhead. The default values of the profiling interval and the overflow value have been chosen as a compromise between obtaining good statistics and minimizing the overhead. Smaller values also mean more data.

For a clock profiling experiment or hardware counter profiling experiment with a profiling interval of about 100 samples per second, and a packet size ranging from 80 bytes for a small call stack up to 120 bytes for a large call stack, data is recorded at a rate of 10 kbytes per second per thread. Applications that have call stacks with a depth of hundreds of calls could easily record data at ten times these rates.

For MPI tracing experiments, the data volume is 100 ‑ 150 bytes per traced MPI call, depending on the number of messages sent and the depth of the call stack. In addition, clock profiling is enabled by default when you use the `-M` option of the `collect` command, so add the estimated numbers for a clock profiling experiment. You can reduce data volume for MPI tracing by disabling clock profiling with the `-p off` option.

Note - The Collector stores MPI tracing data in its own format (`mpview.dat3`) and also in the VampirTrace OTF format (`a.otf`, `a.*.z`). You can remove the OTF format files without affecting Performance Analyzer.

Your estimate of the size of the experiment should also take into account the disk space used by the archive files (see “Where the Data Is Stored” on page 63). If you are not sure how much space you need, try running your experiment for a short time. From this test you can obtain the size of the archive files, which are independent of the data collection time, and scale the size of the profile files to obtain an estimate of the size for the full-length experiment.

Archives might also have copies of all shared objects and some or all of the source files. See “`er_archive` Utility” on page 259 for more information.

As well as allocating disk space, the Collector allocates buffers in memory to store the profile data before writing it to disk. Currently no way exists to specify the size of these buffers. If the Collector runs out of memory, try to reduce the amount of data collected.

If your estimate of the space required to store the experiment is larger than the space you have available, consider collecting data for part of the run rather than the whole run. You can collect data on part of the run with the `collect` command with `-y` or `-t` options, with the `dbx collector` subcommands, or by inserting calls in your program to the collector API. You can also limit the total amount of profiling and tracing data collected with the `collect` command with the `-L` option, or with the `dbx collector` subcommands.

See the article *Data Selectivity and the Oracle Developer Studio Performance Analyzer* for information about selective data collection and analysis, available via the Oracle Developer Studio web page `http://www.oracle.com/technetwork/server-storage/developerstudio`.

Collecting Data

You can collect performance data on user-mode targets in several ways:

- Using the `collect` command from the command line (see "Collecting Data Using the `collect` Command" on page 67 and the `collect`(1) man page). The `collect` command-line tool has smaller data collection overheads than `dbx` so this method can be superior to the others.
- Using the Profile Application dialog box in Performance Analyzer. (See "Profiling an Application" in the Performance Analyzer help.)
- Using the `collector` command from the `dbx` command line. (See "Collecting Data Using the `dbx collector` Subcommands" on page 88).

Collecting data automatically on descendant processes can only be done from the Profile Application dialog box and the `collect` command.

You can collect performance data on the Oracle Solaris kernel using the `er_kernel` utility or the Profile Kernel dialog box. See Chapter 9, "Kernel Profiling" for more information.

Collecting Data Using the `collect` Command

To run the Collector from the command line using the `collect` command, type the following.

```
% collect collect-options program program-arguments
```

collect-options are the `collect` command options, *program* is the name of the program you want to collect data on, and *program-arguments* are the program's arguments. The target program is typically a binary executable or a script.

If invoked with no arguments, `collect` displays a usage summary, including the default configuration of the experiment.

To obtain a list of options and a list of the names of any hardware counters that are available for profiling, type the `collect -h` command with no additional arguments.

```
% collect -h
```

For a description of the list of hardware counters, see "Hardware Counter Profiling Data" on page 28. See also "Limitations on Hardware Counter Profiling" on page 60.

Data Collection Options

These options control the types of data that are collected. See "Data the Collector Collects" on page 23 for a description of the data types.

If you do not specify data collection options, the default is `-p on`, which enables clock profiling with the default profiling interval of approximately 10 milliseconds.

If you explicitly disable clock profiling with `-p off`and do not enable tracing or hardware counter profiling, the `collect` command prints a warning message, and collects global sampling data only.

Clock Profiling with the `-p` *option*

With the `-p` option, you can collect clock profiling data. The allowed values of *option* are:

- `off` – Turn off clock profiling.
- `on` – Turn on clock profiling with the default profiling interval of approximately 10 milliseconds.
- `lo[w]` – Turn on clock profiling with the low-resolution profiling interval of approximately 100 milliseconds.
- `hi[gh]` – Turn on clock profiling with the high-resolution profiling interval of approximately 1 millisecond. See "Limitations on Clock Profiling" on page 59 for information on enabling high-resolution profiling.

- *value* – Turn on clock profiling and set the profiling interval to *value*. The default units for *value* are milliseconds. You can specify *value* as an integer or a floating-point number. The numeric value can optionally be followed by the suffix `m` to select millisecond units or `u` to select microsecond units. The value should be a multiple of the clock resolution. If the value is larger but not a multiple, it is rounded down. If it is smaller, a warning message is printed and it is set to the clock resolution.

Collecting clock profiling data is the default action of the `collect` command. If you do not collect count data (`-c`) or data race and deadlock data (`-r`) then clock profiling data is collected even if you do not specify the `-p` option.

If you specify `-h high` or `-h low` to request the default hardware counters to be set for the processor at high or low-frequency, the default clock profiling is also set to high or low. You can set a different frequency for clock profiling by explicitly setting it with the `-p hi` or `-p low` or `-p` *n* option.

See "Limitations on Clock Profiling" on page 59 for notes about clock-profiling of multithreaded applications on Linux.

Hardware Counter Profiling with `collect -h`

Collect hardware counter profiling data. For some hardware, the `collect` command has defined a default counter set which you can display using `collect -h` without any arguments. You can also specify particular counters instead of using the default counter set. You can use multiple `-h` arguments to specify counters.

See "Hardware Counter Lists" on page 29 for information about the format of the counters displayed with `collect -h`.

The allowed values of *option* used with `collect -h` are:

`off`	Turn off hardware counter profiling. No other options can be specified with `-h off`.
`auto`	Matches the rate used by clock-profiling. If clock-profiling is disabled, use the per-thread maximum rate of approximately 100 samples per second. `auto` is the default and preferred setting.
`lo | low`	User per-thread maximum rate of approximately 10 samples per second.
`on`	User per-thread maximum rate of approximately 100 samples per second.

`hi | high`	User per-thread maximum rate of approximately 1000 samples per second.

ctr_def... [,*ctr_n_def*]

Collect hardware counter profiles using one or more specified counters. The maximum number of counters supported (*ctr_def* through *ctr_n_def*) is processor-dependent. Run `collect -h` without any arguments on the current machine to determine the maximum number of hardware counter definitions for profiling and display the full list of available hardware counters and the default counter set.

Memory-related counters are those with type `load`, `store`, or `load-store` as displayed in the counter list when you run the `collect -h` command without any other command-line arguments. Some such counters are also labeled `precise` or `memoryspace`. For `precise` counters on either SPARC or x86, dataspace and memoryspace data is recorded by default.

Each *ctr_def* counter definition takes the following form:

ctr`[`*~attr=val*`]...[`*~attrN=valN*`][`*/reg#*`],[`*rate*`]`

The meanings of the counter definition options are as follows:

ctr	Processor-specific counter name shown by running the `collect -h` command without any other command-line arguments. On most systems even if a counter is not listed it can still be specified by a numeric value, either in hexadecimal (0x1234) or decimal. Drivers for older chips do not support numeric values, but drivers for more recent chips do. When a counter is specified numerically, the register number should also be specified. The numeric values to use are found in the chip-specific manufacturer's manuals. The name of the manual is given in the `collect -h` output. Some counters are only described in proprietary vendor manuals.
~attr=val	Optional one or more attribute options. On some processors, attribute options can be associated with a hardware counter. If the processor supports attribute options, then running `collect -h` without any other command-line arguments will also provide a list of attribute names to use for *~attr*. The value *val* can be in decimal or hexadecimal format. Hexadecimal format numbers are in C

program format where the number is prepended by a zero and lower-case x (0x*hex_number*). Multiple attributes are concatenated to the counter name. The ~ in front of each attribute name is required.

`/`*reg#*	Hardware register to use for the counter. If not specified, `collect` attempts to place the counter into the first available register and as a result, might be unable to place subsequent counters due to register conflicts. If you specify more than one counter, the counters must use different registers. You can see a list of allowable register numbers by running the `collect -h` command without any other command-line arguments. The `/` character is required if the register is specified.

rate

The sampling frequency. Valid values are as follows:

- `auto` – Matches the rate used by clock profiling. If clock profiling is disabled, use the per-thread maximum rate of 100 samples per second. `auto` is the default and preferred value.
- `lo` – Use the per-thread maximum rate of approximately 10 samples per second.
- `on` – Use the per-thread maximum rate of approximately 100 samples per second.
- `hi` – Use the per-thread maximum rate of approximately 1000 samples per second.
- *value* – Specifies a fixed event interval value to trigger a sample, rather than a sampling rate. When specifying *value*, note that the actual frequency is dependent on the selected counter and the program under test.

  The event interval can be specified in decimal or hexadecimal format. Exercise caution in setting a numerical value, especially as setting the interval too low can overload your application or even your entire system. Generally, aim for fewer than 1000 events per second per thread. You can use the

Performance Analyzer Timeline view to visually estimate the rate of samples.

Note - Setting *value* too low can overload your application or even your entire system. It is recommended you have fewer than 1000 events per second per thread.

The rate can be omitted, in which case `auto` will be used. Even when the rate is omitted, the comma in front of it is required (except for the last counter in a `-h` parameter).

EXAMPLE 2 Valid Examples of `-h` Usage

```
-h auto
-h lo
-h hi
```
Enable the default counters with default, low, or high rates, respectively

```
-h cycles,,insts,,dcm
-h cycles -h insts -h dcm
```
Both have the same meaning: three counters: cycles, insts and dataspace-profiling of D-cache misses (SPARC only)

```
-h cycles~system=1
```
Count cycles in both user and system modes

```
-h 0xc0/0,10000003
```
On Nehalem, that is the equivalent to
```
-h inst_retired.any_p/0,10000003
```

EXAMPLE 3 Invalid Examples of `-h` Usage

```
-h cycles -h off
```
Can't use off with any other -h arguments
```
-h cycles,insts
```
Missing comma, and "insts" does not parse as a number for `<interval>`

If the `-h` argument specifies the use of hardware counters but hardware counters are in use by root at the time the command is given, the `collect` command will report an error and no experiment will be run.

If no `-h` argument is given, no hardware counter profiling data will be collected. An experiment can specify both hardware counter overflow profiling and clock-based profiling. Specifying hardware counter overflow profiling will not disable clock-profiling, even is it is enabled by default.

Synchronization Wait Tracing with `-s` Option

Collect synchronization wait tracing data. The allowed values of *option* are:

`on`

Turn on synchronization delay tracing and set the threshold value by calibration at runtime

`calibrate`

Same as `on`

`off`

Turn off synchronization delay tracing

n

Turn on synchronization delay tracing with a threshold value of *n* microseconds; if *n* is zero, trace all events

`all`

Turn on synchronization delay tracing and trace all synchronization events

By default, turn off synchronization delay tracing.

For Java programs, synchronization tracing might cover Java method calls in the profiled program, native synchronization calls, or both.

On Oracle Solaris, the following functions are traced:

```
mutex_lock()
rw_rdlock()
rw_wrlock()
cond_wait()
```

```
cond_timedwait()
cond_reltimedwait()
thr_join()
sema_wait()
pthread_mutex_lock()
pthread_rwlock_rdlock()
pthread_rwlock_wrlock()
pthread_cond_wait()
pthread_cond_timedwait()
pthread_cond_reltimedwait_np()
pthread_join()
sem_wait()
```

On Linux, the following functions are traced:

```
pthread_mutex_lock()
pthread_cond_wait()
pthread_cond_timedwait()
pthread_join()
sem_wait()
```

Note - Tracing data with the-`H` or `-i` option might produce a very large experiment.

Heap Tracing Data with `-H` *option*

Collect heap tracing data. The allowed values of *option* are:

`on`	Turn on tracing of memory allocation requests
`off`	Turn off tracing of memory allocation requests

Heap tracing is turned off by default.

Heap-tracing events are recorded for any native calls and calls to `mmap` are treated as memory allocations.

Heap profiling is not supported for Java programs. Specifying it is treated as an error.

Note that heap tracing might produce very large experiments. Such experiments are very slow to load and browse.

I/O Tracing with `-i` *option*

Collect I/O trace data. The allowed values of option are:

`on`	Turn on tracing of I/O operations
`off`	Turn off tracing of I/O operations

I/O tracing is not performed by default. I/O tracing might produce very large experiments and such experiments are very slow to load and browse.

Count Data with `-c` *option*

Record count data.

The allowed values of *option* are:

`on`	Turn on count data.
`static`	Turn on simulated count data, based on the assumption that every instruction was executed exactly once.
`off`	Turn off count data.

By default, turn off collection of count data. Count data cannot be collected with any other type of data.

For count data and simulated count data, the executable and any shared objects that are instrumented and statically linked are counted. For count data, but not simulated count data, dynamically loaded shared objects are also instrumented and counted.

On Oracle Solaris, no special compilation is needed although the count option is incompatible with compile flags `-p, -pg, -qp, -xpg`, and `--xlinkopt`.

On Linux, the executable must be compiled with the `-annotate=yes` flag in order to collect count data.

On Oracle Linux 5 instability of the runtime linker audit interface (also called rtld-audit or LD_AUDIT) might prevent collection of count data.

Specify Count Data Instrumentation Directory with **`-I`** *directory*

Specify a directory for count data instrumentation. This option is available only on Oracle Solaris systems, and is meaningful only when the `-c` option is also specified.

Specify Excluded Libraries with **`-N`** *library-name*

Specify a library to be excluded from count data instrumentation, whether the library is linked into the executable or loaded with `dlopen()`. This option is available only on Oracle Solaris systems, and is meaningful only when the `-c` option is also specified. You can specify multiple `-N` options.

Sample Data with **`-S`** *option*

Record sample packets periodically. The allowed values of *option* are:

`off`	Turn off periodic sampling.
`on`	Turn on periodic sampling with the default sampling interval (1 second).
n	Turn on periodic sampling with a sampling interval of *n* in seconds; *n* must be positive.

By default, periodic sampling at 1 second intervals is enabled.

If no data specification arguments are supplied, clock profiling is performed using the default resolution.

If clock profiling is explicitly disabled, and neither hardware counter overflow profiling nor any kind of tracing is enabled, `collect` displays a warning that no function-level data is being collected, then executes the target and record global data.

Data Race and Deadlock Detection with **`-r`** *option*

Collect data for data race detection or deadlock detection for the Thread Analyzer.

The allowed values of *option* are:

`race`

Collect data for detecting data races.

`deadlock`

Collect data for detecting deadlocks and potential deadlocks.

`all`

Collect data for detecting data races, deadlocks, and potential deadlocks. Can also be specified as `race,deadlock`.

`off`

Turn off data collection for data races, deadlocks, and potential deadlocks.

`on`

Collect data for detecting data races (same as `race`).

`terminate`

If an unrecoverable error is detected, terminate the target process.

`abort`

If an unrecoverable error is detected, terminate the target process with a core dump.

`continue`

If an unrecoverable error is detected, allow the process to continue.

By default, turn off collection of all Thread Analyzer data. The `terminate`, `abort`, and `continue` options can be added to any data-collection options, and govern the behavior when an unrecoverable error occurs, such as a real (not potential) deadlock. The default behavior is `terminate`.

Thread Analyzer data cannot be collected with any tracing data, but can be collected in conjunction with clock- or hardware counter profiling data. Thread Analyzer data significantly slows down the execution of the target, and profiles might not be meaningful as applied to the user code.

Thread Analyzer experiments can be examined with either `analyzer` or with `tha`. Thread Analyzer (`tha`) displays a simplified list of default data views, but is otherwise identical.

Before you enable data-race detection, you must instrument executables either at compile time, or by invoking a post- processor. If the target is not instrumented, and none of the shared objects on its library list is instrumented, a warning is displayed, but the experiment is run. Other Thread Analyzer data do not require instrumentation.

For more information about the `collect -r` command and Thread Analyzer, see the *Oracle Developer Studio 12.6: Thread Analyzer User's Guide* and the `tha`(1) man page.

MPI Profiling with `-M` *option*

Specify collection of an MPI experiment. The target of the `collect` command must be the `mpirun` command, and its options must be separated from the target programs to be run by the `mpirun` command by a `--` option. (Always use the `--` option with the `mpirun` command so that you can collect an experiment by prepending the `collect` command and its option to the `mpirun` command line.) The experiment is named as usual and is referred to as the founder experiment. Its directory contains subexperiments for each of the MPI processes, named by rank.

The allowed values of *option* are:

MPI-version

Turn on collection of an MPI experiment, assuming the MPI version named. The recognized versions of MPI are printed when you type `collect` with no arguments, or in response to an unrecognized version specified with `-M`.

`off`

Turn off collection of an MPI experiment.

By default, collection of an MPI experiment is turned off. When collection of an MPI experiment is turned on, the default setting for the `-m` option is changed to `on`.

The supported versions of MPI are printed when you type the `collect -h` command with no additional options, or if you specify an unrecognized version with the `-M` option.

MPI Tracing with `-m` *option*

Collect MPI tracing data.

The allowed values of *option* are:

`on`	Turn on MPI tracing information.
`off`	Turn off MPI tracing information.

MPI tracing is turned off by default unless the `-M` option is enabled, in which case MPI tracing is turned on by default. Normally, MPI experiments are collected with the `-M` option, and no user control of MPI tracing is needed. If you want to collect an MPI experiment but not collect MPI tracing data, use the explicit options `-M` *MPI-version* `-m off`.

See "MPI Tracing Data" on page 35 for more information about the MPI functions whose calls are traced and the metrics that are computed from the tracing data.

Experiment Control Options

These options control aspects of how the experiment data is collected.

Limit the Experiment Size with `-L` *size*

Limit the amount of profiling data recorded to *size* megabytes. The limit applies to the sum of all profiling data and tracing data, but not to sample points. The limit is only approximate, and can be exceeded.

When the limit is reached, no more profiling and tracing data is recorded but the experiment remains open until the target process terminates. If periodic sampling is enabled, sample points continue to be written.

The allowed values of *size* are:

`unlimited` or `none`

Do not impose a size limit on the experiment.

n

Impose a limit of *n* megabytes. The value of *n* must be positive and greater than zero.

By default, there is no limit on the amount of data recorded.

To impose a limit of approximately 2 Gbytes, for example, specify `-L 2000`.

Follow Processes with the `-F` *option*

Control whether descendant processes should have their data recorded. Data is always collected on the founder process independent of the `-F` setting. The allowed values of *option* are:

`on`

Record experiments on all descendant processes.

`all`

Same as `on`

`off`

Do not record experiments on any descendant processes.

=*regex*

Record experiments on those descendant processes whose executable name matches the regular expression. Only the basename of the executable is used, not the full path. If the *regex* that you use contains blanks or characters interpreted by your shell, be sure to enclose the full *regex* argument in single quotes.

The `-F on` option is set by default so that the Collector follows processes created by calls to the functions `fork`(2), `fork1`(2), `fork`(3F), `vfork`(2), and `exec`(2) and its variants. The call to `vfork` is replaced internally by a call to `fork1`.

Descendant processes created by calls to `system`(3C), `system`(3F), `sh`(3F), `posix_spawn`(3p), `posix_spawnp`(3p), and `popen`(3C), and similar functions, and their associated descendant processes are also followed.

On Linux, descendants created by `clone`(2) without the `CLONE_VM` flag are followed by default. Descendants created with the `CLONE_VM` flag are treated as threads rather than processes and are always followed, independent of the `-F` setting.

If you specify the `-F '=` *regexp*`'` option, the Collector follows all descendant processes. The Collector creates a subexperiment when the descendant name or subexperiment name matches the specified regular expression. See the `regexp`(5) man page for information about regular expressions.

Examples using regular expressions:

- To capture data on the descendant process of the first exec from the first fork from the first call to system in the founder, use: `collect -F '=_x1_f1_x1'`

- To capture data on all the variants of exec, but not fork, use: `collect -F '=.*_x[0-9]/*'`
- To capture data from a call to system ("echo hello") but not system ("goodbye"), use: `collect -F '=echo hello'`

For more information about how experiments for descendant processes are created and named, see "Subexperiments" on page 195.

For MPI experiments, descendants are also followed by default.

Performance Analyzer and the `er_print` utility automatically read experiments for descendant processes when the founder experiment is read, and show descendants in the data display.

To select the data of a particular subexperiment for display from the command line, specify the subexperiment path name explicitly as an argument to the `er_print` or `analyzer` commands. The specified path must include the founder experiment name and the descendant experiment name inside the founder directory.

For example, to see the data for the third fork of the `test.1.er` experiment:

```
er_print test.1.er/_f3.er
```

```
analyzer test.1.er/_f3.er
```

Alternatively, you can prepare an experiment group file with the explicit names of the descendant experiments in which you are interested. See "Experiment Groups" on page 64 for more information.

Note - If the founder process exits while descendant processes are being followed, collection of data from descendants that are still running will continue. The founder experiment directory continues to grow accordingly.

You can also collect data on scripts and follow descendant processes of scripts. See "Collecting Data From Scripts" on page 98 for more information.

Profile Java with `-j` *option*

Enable Java profiling when the target program is a JVM. The allowed values of *option* are:

`on`

Record profiling data for the JVM machine, and recognize methods compiled by the Java HotSpot virtual machine, and also record Java call stacks. This is the default.

`off`

Disable recording of Java profiling data. Profiling data for native callstacks will still be recorded.

path

Record profiling data for the JVM, and use the JVM installed in the specified *path*.

Pass Java Options with `-J` *java-argument*

Specify additional arguments to be passed to the JVM used for profiling. If you specify the `-J` option, Java profiling (`-j on`) will be enabled. The *java-argument* must be enclosed in quotation marks if it contains more than one argument. It must consist of a set of tokens separated by blanks or tabs. Each token is passed as a separate argument to the JVM. Most arguments to the JVM must begin with a dash character (-).

Specify a Signal for Sampling with `-l` *signal*

Record a sample packet when the signal named *signal* is delivered to the process.

You can specify the signal by the full signal name, by the signal name without the initial letters `SIG`, or by the signal number. Do not use a signal that is used by the program or that would terminate execution. Suggested signals are `SIGUSR1` and `SIGUSR2`. `SIGPROF` can be used even when clock-profiling is specified. Signals can be delivered to a process by the `kill` command.

If you use both the `-l` (a lower case L) and the `-y` options, you must use different signals for each option.

If you use this option and your program has its own signal handler, you should make sure that the signal that you specify with `-l` is passed on to the Collector's signal handler and is not intercepted or ignored.

See the `signal`(3HEAD) man page for more information about signals.

Set a Time Range with `-t` *duration*

Specify a time range for data collection.

The *duration* can be specified as a single number, with an optional `m` or `s` suffix, to indicate the time in minutes or seconds at which the experiment should be terminated. By default, the duration is in seconds. The *duration* can also be specified as two such numbers separated by a hyphen, which causes data collection to pause until the first time elapses. At that time, data collection begins. When the second time is reached, data collection terminates. If the second number is a zero, data will be collected after the initial pause until the end of the program's run. Even if the experiment is terminated, the target process is allowed to run to completion.

Stop Profiled Target to Allow `dbx` attach with `-x`

Leave the target process stopped on exit from the `exec` system call in order to allow a debugger to attach to it. The `collect` command prints a message with the process ID.

To attach a debugger to the target once it is stopped by `collect`, you can follow the procedure below.

1. Obtain the PID of the process from the message printed by the collect -x command
2. Invoke the `collect` command with the `-P` *PID* option to collect data.

   Alternatively, you could do it manually with the following steps:

   a. Start the debugger
   b. Configure the debugger to ignore SIGPROF and, if you chose to collect hardware counter data, SIGEMT on Oracle Solaris or SIGIO on Linux
   c. Attach to the process using the `dbx attach` command.
   d. Set the collector parameters for the experiment you wish to collect
   e. Issue the `collector enable` command
   f. Issue the `cont` command to allow the target process to run

As the process runs under the control of the debugger, the Collector records an experiment.

Alternatively, you can attach to the process and collect an experiment using the `collect -P` *PID* command.

Signal Pause and Resume State with `-y` *signal* `[ ,r]`

Control recording of data with the signal named *signal*. Whenever the signal is delivered to the process, it switches between the paused state, in which no data is recorded, and the recording state, in which data is recorded.

By default data collection begins in the paused state. If you specify the optional `,r` flag, data collection begins in the resumed state which means profiling occurs immediately. Sample points are always recorded, regardless of the state of the `-y` option.

One use of the pause-resume signal is to start a target without collecting data, allowing it to reach steady-state, and then enabling the data collection.

The signal can be specified by the full signal name, by the signal name without the initial letters `SIG`, or by the signal number. Do not use a signal that is used by the program or that would terminate execution. Suggested signals are `SIGUSR1` and `SIGUSR2`. `SIGPROF` can be used, even when clock-profiling is specified. Signals can be delivered to a process by the `kill` command.

If you use both the `-l` and the `-y` options, you must use different signals for each option.

When the `-y` option is used, the Collector is started in the recording state if the optional `r` argument is given. Otherwise, it is started in the paused state. If the `-y` option is not used, the Collector is started in the recording state.

If you use this option and your program has its own signal handler, make sure that the signal that you specify with `-y` is passed on to the Collector's signal handler, and is not intercepted or ignored.

See the `signal`(3HEAD) man page for more information about signals.

Output Options

These options control aspects of the experiment produced by the Collector.

Set Experiment Name with `-o` *experiment-name*

Use *experiment-name* as the name of the experiment to be recorded. The *experiment-name* string must end in the string "`.er`"; if not, the `collect` utility prints an error message and exits.

If you do not specify the `-o` option, give the experiment a name of the form *stem*`.`*n*`.er`, where *stem* is a string, and *n* is a number. If you have specified a group name with the `-g` option, set *stem* to the group name without the `.erg` suffix. If you have not specified a group name, set *stem* to the string `test`.

If you are invoking the `collect` command from one of the commands used to run MPI jobs, for example, `mpirun`, but without the `-M` *MPI-version* option and the `-o` option, take the value of *n* used in the name from the environment variable used to define the MPI rank of that process. Otherwise, set *n* to one greater than the highest integer currently in use.

If the name is not specified in the form *stem*`.`*n*`.`*er* and the given name is in use, an error message is displayed and the experiment is not run. If the name is of the form *stem*`.`*n*`.`*er* and the name supplied is in use, the experiment is recorded under a name corresponding to one greater than the highest value of *n* that is currently in use. A warning is displayed if the name is changed.

Set Directory of Experiment with `-d` *directory-name*

Place the experiment in directory *directory-name*. This option only applies to individual experiments and not to experiment groups. If the directory does not exist, the `collect` utility prints an error message and exits. If a group is specified with the `-g` option, the group file is also written to *directory-name*.

For the lightest-weight data collection,recording data to a local file is best, using the `-d` option to specify a directory in which to put the data. However, for MPI experiments on a cluster, the founder experiment must be available at the same path for all processes to have all data recorded into the founder experiment.

Experiments written to long-latency file systems are especially problematic and might progress very slowly, especially if Sample data is collected (`-S on` option, the default). If you must record over a long-latency connection, disable Sample data.

Create Experiment in a Group with `-g` *group-name*

Make the experiment part of experiment group *group-name*. If *group-name* does not end in `.erg`, the `collect` utility prints an error message and exits. If the group exists, the experiment is added to it. If *group-name* is not an absolute path, the experiment group is placed in the directory *directory-name* if a directory has been specified with `-d`., Otherwise, it is placed in the current directory.

Archive Load Objects in Experiment with the `-A` *option*

Control whether load objects used by the target process should be archived or copied into the recorded experiment. The allowed values of option are:

- `on` – Copy load objects (the target and any shared objects it uses) into the experiment. Also copy any `.anc` files and `.o` files that have Stabs or DWARF debugging information that is not in the load object. This is the default.
- `src`–In addition to copying load objects as in `-A on`, copy into the experiment all source files and `.anc` files that can be found.

- `used[src]`–In addition to copying load objects as in `-A on`, copy into the experiment all source files and `.anc` files that are referenced in the recorded data and can be found.
- `off` – Do not copy or archive load objects into the experiment.

If you expect to copy experiments to a different machine, or to read the experiments from a different machine, specify `-A on`. The experiment will use more disk space but allows the experiment to be read on other machines.

`-A on` does not copy any source files or object (`.o`) files into the experiment. You must ensure that those files are accessible from the machine on which you are examining the experiment. The files should not be changed or rebuilt after the experiment was recorded.

Archiving of an experiment at collection time, especially for experiments with many descendant processes, can be very expensive. A better strategy for such an experiment is to collect the data with `-A off`, and then run `er_archive` with the `-A` flag after the run is terminated.

The default setting for `-A` is on.

Save the Command Output to a File with `-O` *file*

Append all output from `collect` itself to the named *file*, but do not redirect the output from the spawned target, nor from `dbx` (as invoked with the `-P` option), nor from the processes involved in recording count data (as invoked with the `-c` argument). If *file* is set to `/dev/null`, suppress all output from `collect`, including any error messages.

Other Options

These `collect` command options are used for miscellaneous purposes.

Attach to a Process with `-P` *process-id*

Write a script for `dbx` to attach to the process with the given *process-id*, collect data from it, and then invoke `dbx` with that script.

Clock or hardware counter profiling data can be specified, but neither tracing nor count data are supported. See the `collector`(1) man page for more information.

When attaching to a process, the directory is created with the umask of the user running `collect -P`, but the experiment is written as the user running the process to which dbx attaches. If the user doing the attach is `root`, and the umask is not zero, the experiment will fail.

Add a Comment to the Experiment with `-C` *comment*

Put the comment into the `notes` file inside the experiment. You can supply up to ten `-C` options. The contents of the notes file are prepended to the experiment header.

Try Out a Command with `-n`

Do not run the target but print the details of the experiment that would be generated if the target were run. This option is a dry run option.

Display the `collect` Version with `-V`

Print the current version of the `collect` command. No further arguments are examined, and no further processing is done.

Display Verbose Output with `-v`

Print the current version of the `collect` command and detailed information about the experiment being run.

Collecting Data From a Running Process Using the `collect` Utility

On Oracle Solaris platforms only, the `-P` *pid* option can be used with the `collect` utility to attach to the process with the specified PID, and collect data from the process. The other options to the `collect` command are translated into a script for `dbx`, which is then invoked to collect the data. Only clock profile data (`-p` option) and hardware counter profile data (`-h` option) can be collected. Tracing data is not supported.

If you use the `-h` option without explicitly specifying a `-p` option, clock profiling is turned off. To collect both hardware counter data and clock data, you must specify both a `-h` option and a `-p` option.

▼ To Collect Data From a Running Process Using the `collect` Utility

1. **Determine the program's process ID (PID).**

   If you started the program from the command line and put it in the background, its PID will be printed to standard output by the shell. Otherwise, you can determine the program's PID by typing the following command.

   ```
   % ps -ef | grep program-name
   ```

2. **Use the `collect` command to enable data collection on the process, and set any optional parameters.**

   ```
   % collect -P pid collect-options
   ```

   The collector options are described in "Data Collection Options" on page 68. For information about clock profiling, see "Clock Profiling with the `-p` *option*" on page 68. For information about hardware clock profiling, see "Hardware Counter Profiling with `collect -h`" on page 69.

Collecting Data Using the `dbx collector` Subcommands

This section shows how to run the Collector from `dbx`, and then explains each of the subcommands that you can use with the `collector` command within `dbx`.

▼ To Run the Collector From `dbx`

1. **Load your program into `dbx` by typing the following command.**

   ```
   % dbx program
   ```

2. **Use the `collector` command to enable data collection, select the data types, and set any optional parameters.**

```
(dbx) collector subcommand
```

To see a listing of available `collector` subcommands, type:

```
(dbx) help collector
```

You must use one `collector` command for each subcommand.

3. **Set up any `dbx` options and run the program.**

   If a subcommand is incorrectly given, a warning message is printed and the subcommand is ignored. The following section provides a complete listing of the `collector` subcommands.

Data Collection Subcommands

The following subcommands can be used with the `collector` command within `dbx` to control the types of data that are collected by the Collector. They are ignored with a warning if an experiment is active.

`profile` *option*

Controls the collection of clock profiling data. The allowed values for *option* are:

- `on` – Enables clock profiling with the default profiling interval of 10 ms.
- `off` – Disables clock profiling.
- `timer` *interval* - Sets the profiling interval. The allowed values of *interval* are:
  - `on` – Use the default profiling interval of approximately 10 milliseconds.
  - `lo[w]` – Use the low-resolution profiling interval of approximately 100 milliseconds.
  - `hi[gh]` – Use the high-resolution profiling interval of approximately 1 millisecond. See "Limitations on Clock Profiling" on page 59 for information on enabling high-resolution profiling.
  - *value* - Set the profiling interval to *value*. The default units for *value* are milliseconds. You can specify *value* as an integer or a floating-point number. The numeric value can optionally be followed by the suffix `m` to select millisecond units or `u` to select microsecond units. The value should be a multiple of the clock resolution. If the value is larger than the clock resolution but not a multiple, it is rounded down. If the value is smaller than the clock resolution it is set to the clock resolution. In both cases, a warning message is printed.

The default setting is approximately 10 milliseconds.

The Collector collects clock profiling data by default, unless the collection of hardware-counter profiling data is turned on using the `hwprofile` subcommand.

`hwprofile` *option*

Controls the collection of hardware counter profiling data. If you attempt to enable hardware counter profiling on systems that do not support it, `dbx` returns a warning message and the command is ignored. The allowed values for *option* are:

- `on` – Turns on hardware counter profiling. The default action is to collect data for the `cycles` counter at the normal overflow value.
- `off` – Turns off hardware counter profiling.
- `list` – Returns a list of available counters. See "Hardware Counter Lists" on page 29 for a description of the list. If your system does not support hardware counter profiling, `dbx` returns a warning message.
- `counter` *counter-definition*... `[,` *counter-definition* `]` – A counter definition takes the following form.

  [+]*counter-name*[~ *attribute_1*=*value_1*]...[~*attribute_n* =*value_n*]`[/` *register-number*`]` `[,`*rate* `]`

  Selects the hardware counter *name* and sets its overflow value to *rate*; optionally selects additional hardware counter names and sets their overflow values to the specified rate. The sampling frequency *rate* has the following valid values:

  - `auto`– Match the rate used by clock-profiling. If clock-profiling is disabled, use the per-thread maximum rate of approximately 100 samples per second. `auto` is the default and preferred setting.
  - `lo[w]` – Use the per-thread maximum rate of approximately 10 samples per second.
  - `hi[gh]` – Use the per-thread maximum rate of approximately 10 samples per second.
  - *value* – Specify a fixed event interval value to trigger a sample, rather than a sampling rate. When specifying *value*, note that the actual frequency is dependent on the selected counter and the program under the test.

    If you specify more than one counter, each counter must use different registers. If they do not, a warning message is printed and the command is ignored.

    If the hardware counter counts events that relate to memory access, you can prefix the counter name with a + sign to turn on searching for the true PC of the instruction that caused the counter overflow. If the search is successful, the PC and the effective address that was referenced are stored in the event data packet.

The Collector does not collect hardware counter profiling data by default. If hardware-counter profiling is enabled and a `profile` command has not been issued, clock profiling is turned off.

See also “Limitations on Hardware Counter Profiling” on page 60.

`synctrace` *option*

Controls the collection of synchronization wait tracing data. The allowed values for *option* are:

- `on` – Enable synchronization wait tracing with the default threshold.
- `off` – Disable synchronization wait tracing.
- `threshold` *value* - Sets the threshold for the minimum synchronization delay. The allowed values for *value* are:
  - `all` – Use a zero threshold. This option forces all synchronization events to be recorded.
  - `calibrate` – Set the threshold value by calibration at runtime. (Equivalent to `on`.)
  - `off` – Turn off synchronization wait tracing.
  - `on` – Use the default threshold, which is to set the value by calibration at runtime. (Equivalent to `calibrate`.)
  - *number* - Set the threshold to *number*, given as a positive integer in microseconds. If `value` is 0, all events are traced.

    By default, the Collector does not collect synchronization wait tracing data.

`heaptrace` *option*

Controls the collection of heap tracing data. The allowed values for *option* are:

- `on` – Enable heap tracing.
- `off` – Disable heap tracing.

By default, the Collector does not collect heap tracing data.

`tha` *option*

Collect data for data race detection or deadlock detection for the Thread Analyzer. The allowed values are:

- `off` – Turn off thread analyzer data collection.
- `all` – Collect all thread analyzer data.
- `race` – Collect data-race-detection data.
- `deadlock` – Collect deadlock and potential-deadlock data.

For more information about the Thread Analyzer, see the *Oracle Developer Studio 12.6: Thread Analyzer User's Guide* and the `tha`.1 man page.

`sample` *option*

Controls the sampling mode. The allowed values for *option* are:

- `periodic` – Enable periodic sampling.
- `manual` – Disable periodic sampling. Manual sampling remains enabled.
- `period` *value* – Set the sampling interval to *value*, given in seconds.

By default, periodic sampling is enabled, with a sampling interval *value* of 1 second.

`dbxsample` { `on` | `off` }

Controls the recording of samples when `dbx` stops the target process. The meanings of the keywords are as follows:

- `on` – A sample is recorded each time `dbx` stops the target process.
- `off` – Samples are not recorded when `dbx` stops the target process.

By default, samples are recorded when `dbx` stops the target process.

Experiment Control Subcommands

The following subcommands can be used with the `collector` command within `dbx` to control the collection of experiment data by the Collector. The subcommands are ignored with a warning if an experiment is active.

`disable` Subcommand

Disable data collection. If a process is running and collecting data, it terminates the experiment and disables data collection. If a process is running and data collection is disabled, it is ignored with a warning. If no process is running, it disables data collection for subsequent runs.

`enable` Subcommand

Enable data collection. If a process is running but data collection is disabled, it enables data collection and starts a new experiment. If a process is running and data collection is enabled, it is ignored with a warning. If no process is running, it enables data collection for subsequent runs.

You can enable and disable data collection as many times as you like during the execution of any process. Each time you enable data collection, a new experiment is created.

`pause` Subcommand

Suspends the collection of data but leaves the experiment open. Sample points are not recorded while the Collector is paused. A sample is generated prior to a pause, and another sample is generated immediately following a resume. This subcommand is ignored if data collection is already paused.

`resume` Subcommand

Resumes data collection after a `pause` has been issued. This subcommand is ignored if data is being collected.

`sample record` *name* Subcommand

Record a sample packet with the label *name*. The label is displayed in the Selection Details window of Performance Analyzer.

Output Subcommands

The following subcommands can be used with the `collector` command within `dbx` to define storage options for the experiment. The subcommands are ignored with a warning if an experiment is active.

`archive` *mode* Subcommand

Set the mode for archiving the experiment. The allowed values for *mode* are:

- `on` – Normal archiving of load objects
- `off` – No archiving of load objects
- `copy` – Copy load objects into experiment in addition to normal archiving

If you intend to move the experiment to a different machine or read it from another machine, you should enable the copying of load objects. If an experiment is active, the command is ignored with a warning. This command does not copy source files or object files into the experiment.

`limit` *value* Subcommand

Limit the amount of profiling data recorded to *value* megabytes. The limit applies to the sum of the amounts of clock profiling data, hardware counter profiling data, and synchronization wait tracing data, but not to sample points. The limit is only approximate, and can be exceeded.

When the limit is reached, no more profiling data is recorded but the experiment remains open and sample points continue to be recorded.

By default, the amount of data recorded is unlimited.

`store` *option* Subcommand

Governs where the experiment is stored. This command is ignored with a warning if an experiment is active. The allowed values for *option* are:

- `directory` *directory-name* – Sets the directory where the experiment and any experiment group is stored. This subcommand is ignored with a warning if the directory does not exist.

- `experiment` *experiment-name* – Sets the name of the experiment. If the experiment name does not end in `.er`, the subcommand is ignored with a warning. See "Where the Data Is Stored" on page 63 for more information on experiment names and how the Collector handles them.
- `group` *group-name* – Sets the name of the experiment group. If the group name does not end in `.erg`, the subcommand is ignored with a warning. If the group already exists, the experiment is added to the group. If the directory name has been set using the `store directory` subcommand and the group name is not an absolute path, the group name is prefixed with the directory name.

Information Subcommands

The following subcommands can be used with the `collector` command within `dbx` to get reports about Collector settings and experiment status.

`show` Subcommand

Shows the current setting of every Collector control.

`status` Subcommand

Reports on the status of any open experiment.

Collecting Data From a Running Process With `dbx` on Oracle Solaris Platforms

On Oracle Solaris platforms, you can collect data from a running process using the Collector. If the process is already under the control of `dbx`, you can pause the process and enable data collection using the methods described in previous sections. Starting data collection on a running multithreaded process is not supported on Linux platforms.

If the process is not under the control of `dbx`, the `collect –P` *pid* command can be used to collect data from a running process, as described in "Collecting Data From a Running Process Using the `collect` Utility" on page 87. You can also attach `dbx` to it, collect performance data, and then detach from the process, leaving it to continue. If you want to collect performance data for selected descendant processes, you must attach `dbx` to each process.

▼ To Collect Data From a Running Process That Is Not Under the Control of `dbx`

1. **Determine the program's process ID (PID).**

   If you started the program from the command line and put it in the background, its PID will be printed to standard output by the shell. Otherwise you can determine the program's PID by typing the following command:

   ```
   % ps -ef | grep program-name
   ```

2. **Invoke the `collect` command with the `-P` *PID* to collect data.**

   - **Alternatively, you could do it manually using the following steps:**

     a. **Attach to the process.**

        From `dbx`, type the following command:

        ```
        (dbx) attach program-name pid
        ```

        If `dbx` is not already running, type the following command:

        ```
        % dbx program-name pid
        ```

        Attaching to a running process pauses the process.

        See the manual *Oracle Developer Studio 12.6: Debugging a Program with dbx* for more information about attaching to a process.

     b. **Start data collection.**

        From `dbx`, use the `collector` command to set up the data collection parameters and the `cont` command to resume execution of the process.

     c. **Detach from the process.**

        When you have finished collecting data, pause the program and then detach the process from `dbx`.

        From `dbx`, type the following command:

```
(dbx) detach
```

Collecting Tracing Data From a Running Program

If you want to collect any kind of tracing data, you must preload the Collector library, `libcollector.so` , before you run your program. To collect heap tracing data or synchronization wait tracing data, you must also preload `er_heap.so` and `er_sync.so`, respectively. These libraries provide wrappers to the real functions that enable data collection to take place. In addition, the Collector adds wrapper functions to other system library calls to guarantee the integrity of performance data. If you do not preload the libraries, these wrapper functions cannot be inserted. See "Using System Libraries" on page 50 for more information on how the Collector interposes on system library functions.

To preload `libcollector.so`, you must set both the name of the library and the path to the library using environment variables, as shown in the table below. Use the environment variable `LD_PRELOAD` to set the name of the library. Use the environment variables `LD_LIBRARY_PATH`, `LD_LIBRARY_PATH_32`, or `LD_LIBRARY_PATH_64` to set the path to the library. `LD_LIBRARY_PATH` is used if the `_32` and `_64` variants are not defined. If you have already defined these environment variables, add new values to them.

TABLE 7 Environment Variable Settings for Preloading `libcollector.so`, `er_sync.so`, and `er_heap.so`

Environment Variable	Value
`LD_PRELOAD`	`libcollector.so`
`LD_PRELOAD`	`er_heap.so`
`LD_PRELOAD`	`er_sync.so`
`LD_LIBRARY_PATH`	`/opt/developerstudio12.6/lib/analyzer/runtime`
`LD_LIBRARY_PATH_32`	`/opt/developerstudio12.6/lib/analyzer/runtime`
`LD_LIBRARY_PATH_64`	`/opt/developerstudio12.6/lib/analyzer/v9/runtime`
`LD_LIBRARY_PATH_64`	`/opt/developerstudio12.6/lib/analyzer/amd64/runtime`

If your Oracle Developer Studio software is not installed in `/opt/developerstudio12.6`, ask your system administrator for the correct path. You can set the full path in `LD_PRELOAD`, but doing this can create complications when using SPARC® V9 64-bit architecture.

Note - Remove the `LD_PRELOAD` and `LD_LIBRARY_PATH` settings after the run, so they do not remain in effect for other programs that are started from the same shell.

Collecting Data From Scripts

You can specify a script as the target for the `collect` command. When the target is a script, `collect` by default collects data on the program that is launched to execute the script, and on all descendant processes.

To collect data only on a specific process, use the `-F` option to specify the name of the executable to follow.

For example, to profile the script `start.sh`, but collect data primarily from the executable `myprogram`, use the following command.

```
$ collect -F =myprogram start.sh
```

Data is collected on the founder process that is launched to execute the `start.sh` script, and on all `myprogram` processes that are spawned from the script, but not collected for other processes.

Using `collect` With `ppgsz`

You can use `collect` with `ppgsz`(1) by running `collect` on the `ppgsz` command and specifying the `-F on` or `-F all` flag. The founder experiment is on the `ppgsz` executable and uninteresting. If your path finds the 32-bit version of `ppgsz` and the experiment is run on a system that supports 64-bit processes,it will `exec` its 64-bit version, creating `_x1.er`. That executable forks, creating `_x1_f1.er`.

The child process attempts to `exec` the named target in the first directory on your path, then in the second, and so forth, until one of the `exec` attempts succeeds. If, for example, the third attempt succeeds, the first two descendant experiments are named `_x1_f1_x1.er` and `_x1_f1_x2.er`, and both are completely empty. The experiment on the target is the one from the successful `exec`, the third one in the example, and is named `_x1_f1_x3.er`, stored under the founder experiment. It can be processed directly by invoking the Analyzer or the `er_print` utility on `test.1.er/_x1_f1_x3.er`.

If the 64-bit `ppgsz` is the initial process or if the 32-bit `ppgsz` is invoked on a 32-bit kernel, the fork child that `exec`s the real target has its data in `_f1.er` , and the real target’s experiment is in `_f1_x3.er`, assuming the same path properties as in the example above.

Collecting Data From MPI Programs

The Collector can collect performance data from multi-process programs that use the Message Passing Interface (MPI).

The Collector supports the Oracle Message Passing Toolkit 8 (formerly known as Sun HPC ClusterTools 8) and its updates. The Collector can recognize other versions of MPI; the list of valid MPI versions is shown when you run `collect -h` with no additional arguments.

To collect data from MPI jobs, you must use the `collect` command; the `dbx collector` subcommands cannot be used to start MPI data collection. Details are provided in "Running the `collect` Command for MPI" on page 99.

Running the `collect` Command for MPI

The `collect` command can be used to trace and profile MPI applications.

To collect data, use the following syntax:

`collect [`*collect-arguments***`] mpirun [`***mpirun-arguments***`] --`** *program-name* **`[`***program-arguments***`]`**

For example, the following command runs MPI tracing and profiling on each of the 16 MPI processes, storing the data in a single MPI experiment:

```
collect -M OMPT mpirun -np 16 -- a.out 3 5
```

The `-M OMPT` option indicates MPI profiling is to be done and Oracle Message Passing Toolkit is the MPI version.

The initial collect process reformats the `mpirun` command to specify running the `collect` command with appropriate arguments on each of the individual MPI processes.

The `--` argument immediately before the *program_name* is required for MPI profiling. If you do not include the `--` argument, the `collect` command displays an error message and no experiment is collected.

Note - The technique of using the `mpirun` command to spawn explicit `collect` commands on the MPI processes is no longer supported for collecting MPI trace data. You can still use this technique for collecting other types of data.

Storing MPI Experiments

Because multiprocessing environments can be complex, you should be aware of some issues about storing MPI experiments when you collect performance data from MPI programs. These issues concern the efficiency of data collection and storage, and the naming of experiments. See "Where the Data Is Stored" on page 63 for information on naming experiments, including MPI experiments.

Each MPI process that collects performance data creates its own subexperiment. While an MPI process creates an experiment, it locks the experiment directory; all other MPI processes must wait until the lock is released before they can use the directory. Store your experiments on a file system that is accessible to all MPI processes.

If you do not specify an experiment name, the default experiment name is used. Within the experiment, the Collector will create one subexperiment for each MPI rank. The Collector uses the MPI rank to construct a subexperiment name with the form `M_rm.er`, where *m* is the MPI rank.

If you plan to move the experiment to a different location after it is complete, then specify the `-A copy` option with the `collect` command. To copy or move the experiment, do not use the UNIX `cp` or `mv` command. Instead, use the `er_cp` or `er_mv` command as described in Chapter 8, "Manipulating Experiments".

MPI tracing creates temporary files in `/tmp/a.*.z` on each node. These files are removed during the `MPI_finalize()` function call. Make sure that the file systems have enough space for the experiments. Before collecting data on a long-running MPI application, do a short-duration trial run to verify file sizes. Also see "Estimating Storage Requirements" on page 65 for information on how to estimate the space needed.

MPI profiling is based on the open source VampirTrace 5.5.3 release. It recognizes several supported VampirTrace environment variables and a new one, `VT_STACKS`, which controls whether call stacks are recorded in the data. For further information on the meaning of these variables, see the VampirTrace 5.5.3 documentation.

The default value of the environment variable `VT_BUFFER_SIZE` limits the internal buffer of the MPI API trace collector to 64 Mbytes. After the limit has been reached for a particular MPI process, the buffer is flushed to disk if the `VT_MAX_FLUSHES` limit has not been reached. By default, `VT_MAX_FLUSHES` is set to 0. This setting causes the MPI API trace collector to flush the buffer to disk whenever the buffer is full. If you set `VT_MAX_FLUSHES` to a positive number, you limit the number of flushes allowed. If the buffer fills up and cannot be flushed, events are no longer written into the trace file for that process. The result can be an incomplete experiment, and, in some cases, the experiment might not be readable.

To change the size of the buffer, use the environment variable `VT_BUFFER_SIZE`. The optimal value for this variable depends on the application that is to be traced. Setting a small value will increase the memory available to the application but will trigger frequent buffer flushes by the MPI API trace collector. These buffer flushes can significantly change the behavior of the application. On the other hand, setting a large value like 2 Gbytes will minimize buffer flushes by the MPI API trace collector but decrease the memory available to the application. If not enough memory is available to hold the buffer and the application data, parts of the application might be swapped to disk, leading also to a significant change in the behavior of the application.

Another important variable is `VT_VERBOSE`, which turns on various error and status messages. Set this variable to 2 or higher if problems arise.

Normally, MPI trace output data is post-processed when the `mpirun` target exits. A processed data file is written to the experiment and information about the post-processing time is written into the experiment header. MPI post-processing is not done if MPI tracing is explicitly disabled with `-m off`. In the event of a failure in post-processing, an error is reported, and no MPI Tabs or MPI tracing metrics are available.

If the `mpirun` target does not actually invoke MPI, an experiment is still recorded but no MPI trace data is produced. The experiment reports an MPI post-processing error, and no MPI Tabs or MPI tracing metrics will be available.

If the environment variable `VT_UNIFY` is set to `0`, the post-processing routines are not run by `collect`. They are run the first time `er_print` or `analyzer` are invoked on the experiment.

Note - If you copy or move experiments between computers or nodes, you cannot view the annotated source code or source lines in the annotated disassembly code unless you have access to the source files or a copy with the same timestamp. You can put a symbolic link to the original source file in the current directory in order to see the annotated source. You can also use settings in the Settings dialog box. Use the Search Path tab (see "Search Path Settings" on page 145) to manage a list of directories to be used for searching for source files. Use the Pathmaps tab (see "Pathmaps Settings" on page 146) to map the leading part of a file path from one location to another.

♦ ♦ ♦ CHAPTER 4

Performance Analyzer Tool

This chapter describes the Performance Analyzer graphical data analysis tool and covers the following topics:

About Performance Analyzer

Performance Analyzer is a graphical data-analysis tool that analyzes performance data collected by the Collector. The Collector starts when you profile an application from Performance Analyzer or use the `collect` command. The Collector gathers performance information to create an experiment during the execution of a process, as described in Chapter 3, "Collecting Performance Data".

Performance Analyzer reads in such experiments, analyzes the data, and displays the data in tabular and graphical displays.

Note - You can download demonstration code for Performance Analyzer in the sample applications zip file from the Oracle Developer Studio 12.6 web page at `http://www.oracle.com/technetwork/server-storage/developerstudio`.

See the *Oracle Developer Studio 12.6: Performance Analyzer Tutorials* for information about how to use the sample code with Performance Analyzer.

Starting Performance Analyzer

To start Performance Analyzer, type the following command in a terminal window:

`%` **`analyzer`** `[`*control-options*`]` `[`*experiment* | *experiment-list*`]`

You can specify an experiment name or a list. The *experiment-list* command argument is a space-separated list of experiment names, experiment group names, or both. If you do not provide an experiment list, Performance Analyzer starts and opens the Welcome page.

You can specify multiple experiments or experiment groups on the command line. If you specify an experiment that has descendant experiments inside it, all descendant experiments are automatically loaded and the data is aggregated. To load individual descendant experiments, you must specify each experiment explicitly or create an experiment group.

In reading experiments with descendants, any sub-experiments that contain little or no performance data are ignored by Performance Analyzer and `er_print`.

To create an experiment group, you can use the `-g` argument to the `collect` utility. To manually create an experiment group, create a plain text file whose first line is as follows:

```
#analyzer experiment group
```

Then add the names of the experiments on subsequent lines. The file extension must be `erg`.

When Performance Analyzer displays multiple experiments, data from all the experiments is aggregated by default. The data is combined and viewed as if the data is from one experiment. However, you can also choose to compare the experiments instead of aggregating the data if you specify the `-c` option. See "Comparing Experiments" on page 136.

You can preview an experiment or experiment group by clicking its name in the Open Experiment dialog box.

You can also start Performance Analyzer from the command line to record an experiment as follows:

`%` **`analyzer`** `[`*Java-options*`]` `[`*control-options*`]` *target* `[`*target-arguments*`]`

Performance Analyzer starts up with the Profile Application window showing the named target and its arguments and settings for profiling an application and collecting an experiment. See "Profiling Applications From Performance Analyzer" on page 135 for details.

You can also open a "live" experiment – an experiment that is still being collected. When you open a live experiment, you see only the data that had already been collected when you opened the experiment. The experiment is not automatically updated as new data comes in. To update, you can open the experiment again.

`analyzer` Command Options

These `analyzer` command options control the behavior of Performance Analyzer and are divided into the following groups:

- Experiment options
- Java options
- Control options
- Information options

Experiment Options

These options specify how to handle experiments that you specify on the command line.

`-c` *base-group compare-group*

Start Performance Analyzer and compare the specified experiments.

The *base-group* is either a single experiment or a *groupname*`.erg` file which specifies multiple experiments. The *compare-group* is one or more experiments that you want to compare to the base group.

To specify multiple experiments in the compare group, separate the experiment names with spaces. You can also specify a *groupname*`.erg` file which specifies multiple experiments in the compare group.

EXAMPLE 4 Sample Commands for Opening Experiments in Comparison Mode

Open the experiment `test.1.er` and compare it to `test.4.er`:

```
% analyzer -c test.1.er test.4.er
```

Open the experiment group `demotest.erg` and compare it to `test.4.er`:

```
% analyzer -c demotest.erg test.4.er
```

Java Options for `analyzer` Command

These options specify settings for the JVM that runs Performance Analyzer.

`-j | --jdkhome` *jvm-path*

Specify the path to the Java software for running Performance Analyzer. When the `-j` option is not specified, the default path is taken first by examining environment variables for a path to the JVM, in the order `JDK_HOME` and then `JAVA_PATH`. If neither environment variable is set, the JVM found on your PATH is used. Use the `-j` option to override all the default paths.

`-J` *jvm-option*

Specify the JVM options. You can specify multiple options. For example:

- To run the 64–bit Performance Analyzer, type:

  ```
  analyzer -J-d64
  ```
- To run Performance Analyzer with a maximum of JVM memory of 2 Gbytes, type:

  ```
  analyzer -J-Xmx2G
  ```
- To run the 64–bit Performance Analyzer with a maximum JVM memory of 8 Gbytes, type:

  ```
  analyzer -J-d64 -J-Xmx8G
  ```

Control Options for `analyzer` Command

These `analyzer` command options control the location of the user directory where your settings are stored, set the font size of the user interface. and display the version and runtime information before starting Performance Analyzer.

`-f | --fontsize` *size*

Specify the font size to be used in the Performance Analyzer user interface..

To start Performance Analyzer and display the menus in 14-point font, type the following:

```
analyzer -f 14
```

-v | --verbose

Display version information and Java runtime arguments and then start Performance Analyzer.

Information Options for `analyzer` Command

These options print information about `analyzer` to standard output. The individual options below are stand-alone options. They cannot be combined with other `analyzer` options nor combined with target or experiment-list arguments.

-V | --version

Display version information only and do not start Performance Analyzer.

-? | -h | --help

Print usage information and exit.

Performance Analyzer User Interface

The Performance Analyzer window has a menu bar, a toolbar, and a navigation panel. You use each of these to interact with Performance Analyzer and your data.

Menu Bar

The menu bar contains the following command menus.

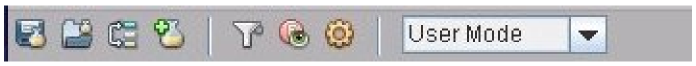
- File provides several options you can use to profile applications, open experiments, and compare or aggregate data from multiple experiments. Other options include the ability to export the content of a data view to several different formats and connect to a remote host use the Performance Analyzer on files and applications located there.

- Views enables you to select the data views that you want Performance Analyzer to display in the navigation bar. You can also click the Views + button or More Views in the navigation bar to add more data views.
- Metrics enables you to view metrics in data views.
- Tools provides options for filtering data, hiding library functions in the data views, and other settings.
- Help provides links to integrated documentation for Performance Analyzer including links to new features, quick reference, keyboard shortcuts, and troubleshooting information. You can also press the F1 key on your keyboard to display information about the current view in Performance Analyzer.

Tool Bar

The toolbar provides buttons you can use as shortcuts for commands, a view mode selector that you can use to change the way data is displayed for Java and OpenMP experiments, and a Find tool to help you locate text in data views.

FIGURE 2 Toolbar of Performance Analyzer



Navigation Panel

The vertical navigation panel on the left enables you to select various pages known as *data views* or simply *views* in Performance Analyzer. Most views show a perspective of the performance metrics for your profiled application. The views are related so that selections you make and filters you apply in one view are applied to other views.

Some buttons on the navigation panel open pages such as the Welcome page which makes the tool easier to use and find information, and the Overview page which provides information about the data in the open experiments.

You can add more views to the navigation panel by clicking the + button at the top of the navigation panel or the More Views button on the bottom of the navigation panel. You can also use the Views menu to select another view to add.

You can click the items in most data views to see more detailed information about the items in the Selection Details window, which is described in the next section "Selection Details Window" on page 109.

The data views are described in "Performance Analyzer Views" on page 109.

Selection Details Window

The Selection Details window on the right side shows all the recorded metrics for the selected item both as values and percentages, and information on the selected function or load object. The Selection Details window is updated whenever a new item is selected in any data view.

When you select a sample in the Samples bar of the Timeline view, the Selection Details window shows the sample number, the start and end time of the sample, and the microstates with the amount of time spent in each microstate and the color coding.

When you select an event in a data bar of the Timeline view, the Selection Details window shows the event details and the call stack.

Called-By/Calls Panel

The Called-by/Calls panel at the bottom of some data views enables you to navigate call paths. Select a function in the view and then use the Called-by/Calls panel to navigate to functions it was called by, or to function calls it makes. When you click a function in Called-by/Calls, the function is selected in the data view.

Performance Analyzer Views

The following factors determine whether a data view is displayed in the navigation bar when you open an experiment:

- The type of data in the experiment determines what data views should be displayed. For example, if an experiment contains OpenMP data, the views for OpenMP are automatically opened to display the data.
- Configuration files which are read when you start Performance Analyzer specify the default data views to display.

You can use the Views menu or button to open the Settings dialog box (see "Views Settings" on page 140) to select the views that you want to display in the current Performance Analyzer session.

Most views have a context menu that opens when you by right-click on an item in the view. You can use the context menu to add filters or to perform other activities related to that data view. When you apply filters in one view, the data is filtered in all the views that can be filtered.

The navigation bar shows the following:

- "Welcome Page" on page 111
- "Overview Screen" on page 112
- "Functions View" on page 114
- "Timeline View" on page 114
- "Source View" on page 116
- "Flame Graph View" on page 118
- "Call Tree View" on page 119
- "Callers-Callees View" on page 119
- "Index Objects Views" on page 120
- "Threads View" on page 121
- "Samples View" on page 121
- "CPUs View" on page 121
- "Seconds View" on page 121
- "Processes View" on page 122
- "Experiment IDs View" on page 122
- "MemoryObjects Views" on page 122
- "DataObjects View" on page 123
- "DataLayout View" on page 123
- "I/O View" on page 124
- "Heap View" on page 124
- "Data Size View" on page 125
- "Duration View" on page 125
- "OpenMP Parallel Region View" on page 125
- "OpenMP Task View" on page 126
- "Lines View" on page 126
- "PCs View" on page 127
- "Disassembly View" on page 127
- "Source/Disassembly View" on page 128
- "Races View" on page 128
- "Deadlocks View" on page 128
- "Dual-Source View" on page 129
- "Inst-Freq View" on page 129
- "Statistics View" on page 129

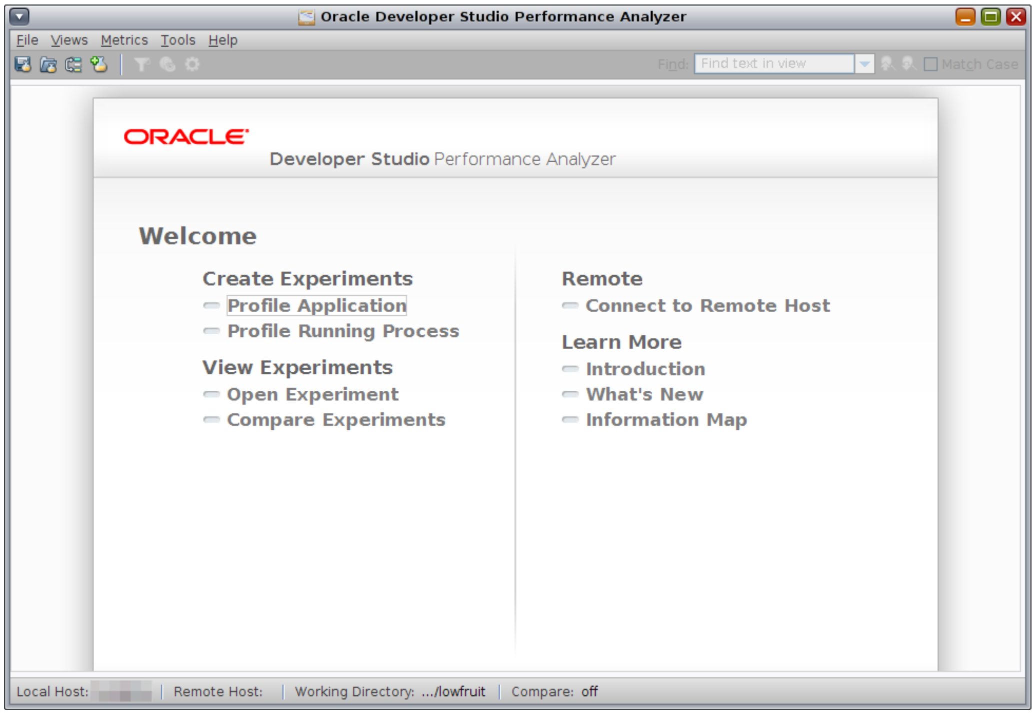
- "Experiments View" on page 129
- "MPI Timeline View" on page 130
- "MPI Chart View" on page 130

Welcome Page

When you start Performance Analyzer without specifying on the command line which experiment to open, the first page you see if the Welcome page. The Welcome page makes it easy to start profiling an application, view recent experiments, compare experiments, and view documentation. After you open an experiment, you can still select the Welcome page from the navigation panel at any time during a Performance Analyzer session.

The following figure shows the Welcome page.

FIGURE 3 Performance Analyzer Welcome Page

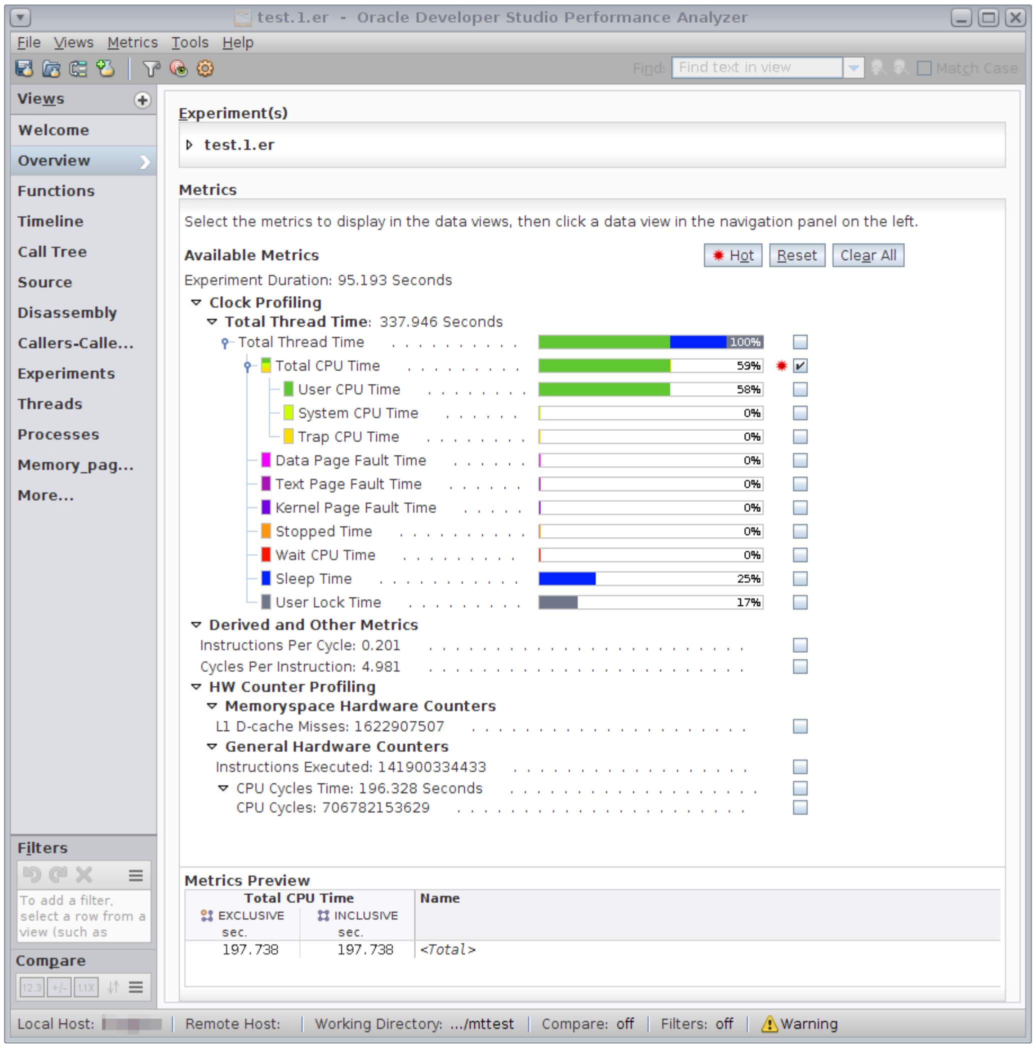


Overview Screen

When you open an experiment Performance Analyzer displays the Overview, which shows performance metrics for the loaded experiments and can give you a quick idea of where the metrics are high. Use the Overview to select the metrics you want to explore in other views. Press F1 while viewing the Overview for detailed information about the Overview.

The following figure shows the Performance Analyzer window with the Overview displayed.

FIGURE 4 Performance Analyzer's Overview Screen



Experiment(s)

test.1.er

Metrics

Select the metrics to display in the data views, then click a data view in the navigation panel on the left.

Available Metrics

Experiment Duration: 95.193 Seconds

- Clock Profiling
  - Total Thread Time: 337.946 Seconds

Metric	%	
Total Thread Time	100%	☐
Total CPU Time	59%	✓
User CPU Time	58%	☐
System CPU Time	0%	☐
Trap CPU Time	0%	☐
Data Page Fault Time	0%	☐
Text Page Fault Time	0%	☐
Kernel Page Fault Time	0%	☐
Stopped Time	0%	☐
Wait CPU Time	0%	☐
Sleep Time	25%	☐
User Lock Time	17%	☐

- Derived and Other Metrics
  - Instructions Per Cycle: 0.201
  - Cycles Per Instruction: 4.981
- HW Counter Profiling
  - Memoryspace Hardware Counters
    - L1 D-cache Misses: 1622907507
  - General Hardware Counters
    - Instructions Executed: 141900334433
    - CPU Cycles Time: 196.328 Seconds
      - CPU Cycles: 706782153629

Metrics Preview

Total CPU Time		Name
EXCLUSIVE sec.	INCLUSIVE sec.	
197.738	197.738	<Total>

Local Host: | Remote Host: | Working Directory: .../mttest | Compare: off | Filters: off | Warning

As you select metrics, the Metrics Preview panel at the bottom of the window show how the metrics will look in the data views. You can specify which metrics you want to see in the data views, by using a selection button or specifically selecting which metrics you are interested in. For more information, see the Overview Screen topic in the help.

Functions View

The Functions view shows a list of the target program's functions and their metrics, which are derived from the data collected in the experiment. Metrics can be either exclusive or inclusive. Exclusive metrics represent usage only by the function itself. Inclusive metrics represent usage by the function and all the functions it called. For more detailed information about metrics, see “Function-Level Metrics: Exclusive, Inclusive, Attributed, and Static” on page 39.

The list of available metrics for each kind of data collected is given in the `collect`(1) man page and the help, and in Chapter 2, “Performance Data”.

Time metrics are shown as seconds, presented to millisecond precision. Percentages are shown to a precision of 0.01%. If a metric value is precisely zero, its time and percentage is shown as “0.” If the value is not exactly zero but is smaller than the precision, its value is shown as “0.000” and its percentage as “0.00”. Because of rounding, percentages may not sum to exactly 100%. Count metrics are shown as an integer count.

The metrics initially shown are based on the data collected. If more than one type of data has been collected, the default metrics for each type are shown. You can select which metrics to display in the Overview page. See “Overview Screen” on page 112 for more information.

To search for a function, use the Find tool in the toolbar.

To view the source code for a function, double-click on it to open the Source view at the correct line in the source code.

To select a single function, click that function and see more information about it in the Selection Details window on the right side.

To select several functions that are displayed contiguously in the view, select the first function of the group, then Shift-click on the last function of the group.

To select several functions that are not displayed contiguously in the view, select the first function of the group, then select the additional functions by Control-clicking on each function.

You can also right-click in the Functions view to open a context menu and select a predefined filter for the selected functions. See the Performance Analyzer help for details about filtering.

Timeline View

The Timeline view shows a chart of the events and the sample points recorded as a function of time. Data is displayed in horizontal bars. By default, for each experiment there is one bar for CPU Utilization Samples at the top and a set of profiling data bars for each thread. The data shown for each thread is determined by the data you collected when you profiled your application.

The Timeline view enables you to do the following with your program:

- Identify phases of program activity
- Highlight functions and methods, using custom coloring
- Zoom in by time and vertical axes to see details
- View complete event information on the Selection Details panel
- Filter global data by time range, threads, and CPUs

You might see the following data bars:

CPU Utilization Samples

When an experiment includes sample data, the top bar displayed is CPU Utilization Samples. Data in a sample point represents CPU time spent between that point and the previous point. Samples data include microstate information, which is available on Oracle Solaris systems.

Oracle Solaris operating systems use a technology called microstate accounting to gather statistics about the execution state for every event. The timing metrics for events shown by Performance Analyzer correspond to the relative amount of time spent in each state. CPU Utilization Samples displays a summary of the timing metrics for all the threads in the experiment. Click a sample to display the timing metrics for that sample in Selection Details panel on the right. You can display timing metrics for individual events in the timeline by displaying event states.

Profiling and Tracing Data Bars

The data bars for clock profiling, hardware counter profiling, and tracing data show an event marker for each event recorded. The event markers consist of a color-coded representation of the call stack that was recorded with the event.

Click an event marker to see information about the event in the Selection Details panel and the call stack functions in the Call Stack panel. Double-click functions in the Call Stack panel to go to the Source view and see the source for the function along with metrics.

For some kinds of data, events can overlap and not be visible. Whenever two or more events would appear at exactly the same position, only one can be drawn; if there are two or more events within one or two pixels, all are drawn, although they may not be visually distinguishable. In either case, a small gray tick mark is displayed below the event indicating the boundaries of that event. You can zoom in to see the events. You can use the left and right arrow keys to move the event selection in either direction and make hidden events become visible. You can see more information about events by displaying event density.

Heap Size

Heap Size data is available only if the `heaptrace` collection option is enabled. Heap Size consists of two graphs. `Net Bytes Allocated` tracks the allocated bytes minus the free byes. `Net Bytes Leaked` shoes the accumulation of allocated bytes that are never freed.

Event States

Events states are shown in a bar chart that shows the distribution of application time spent in various states as a function of time.

For clock profiling data recorded on Oracle Solaris, the event state chart shows Oracle Solaris microstates. The color coding for event states is the same as for the CPU Utilization Samples bar.

Event states are displayed by default. You can hide them by clicking the Timeline Settings button Timeline settings icon in the Timeline toolbar and deselecting Event States in the Timeline area of the Settings dialog box.

Event Density

Event density is indicated by a blue line that displays frequency of events as a function of time.

To show event density, click the Timeline Settings button Timeline settings icon in the timeline toolbar and select Event Density in the Timeline area of the Settings dialog box.

Event density is then displayed immediately below the timeline data bar for each data type. Event density displays the count of events that occurred in each horizontal time slice. The scale of the vertical axis of the line chart is 0 to the highest event count for that specific data bar in the visible time range.

When the Timeline's zoom setting is such that there are many events in each visible time slice, event density can be used to identify periods of high event frequency. To explore such a period, you can zoom in. Then you can right-click and select a context filter to include only data from the visible time range, and analyze that data from that specific period using the other Performance Analyzer data views.

Source View

If the source code is available, the Source view shows the file containing the source code of the selected function, annotated with performance metrics in columns to the left of each source line.

High metrics are highlighted in yellow to indicate source lines that are hot areas of resource usage. An orange navigation marker is also shown in a margin next to the scrollbar on the right for each hot source line. Non-zero metrics that are below the hot threshold are not highlighted, but are flagged with grey navigation markers.

To quickly navigate to source lines with metrics, click the yellow markers in the right margin to jump to the lines with metrics. To jump to the next line with metrics, right-click the metrics themselves and select an option such as Next Hot Line or Next Non-Zero Metric Line.

You can set the threshold for highlighting metrics in the Settings dialog box, in the Source/ Disassembly tab.

The Source view shows the full paths to the source file and the corresponding object file, and the name of the load object in the column heading for the source code. In the rare case where the same source file is used to compile more than one object file, the Source view shows the performance data for the object file containing the selected function.

If Performance Analyzer cannot find a source file, you can click the Resolve button in the Source view to browse to the source file or type the path to the source or browse to it and then the source code is displayed from the new location. Optionally, you can select Archive Source Files Inside Experiment. This will copy the source files into the experiment. For more information about this button, see the Resolve Source File topic in the Help menu.

See "How the Tools Find Source Code" on page 231 for a description of the process used to find an experiment's source code.

When you double-click a function in the Functions view and the Source view is opened, the source file displayed is the default source context for that function. The default source context of a function is the file containing the function's first instruction, which for C code is the function's opening brace. Immediately following the first instruction, the annotated source file adds an index line for the function. The source window displays index lines as text in red italics within angle brackets in the form:

<Function: f_name>

A function might have an alternate source context, which is another file that contains instructions attributed to the function. Such instructions might come from include files or from other functions inlined into the selected function. If there are any alternate source contexts, the beginning of the default source context includes a list of extended index lines that indicate where the alternate source contexts are located.

<Function: f, instructions from source file src.h>

Double-click an index line that refers to another source context opens the file containing that source context at the location associated with the indexed function.

To aid navigation, alternate source contexts also start with a list of index lines that refer back to functions defined in the default source context and other alternate source contexts.

The source code is interleaved with any compiler commentary that has been selected for display. You can set the classes of commentary shown in the Settings dialog box. The default classes can be set in a `.er.rc` defaults file.

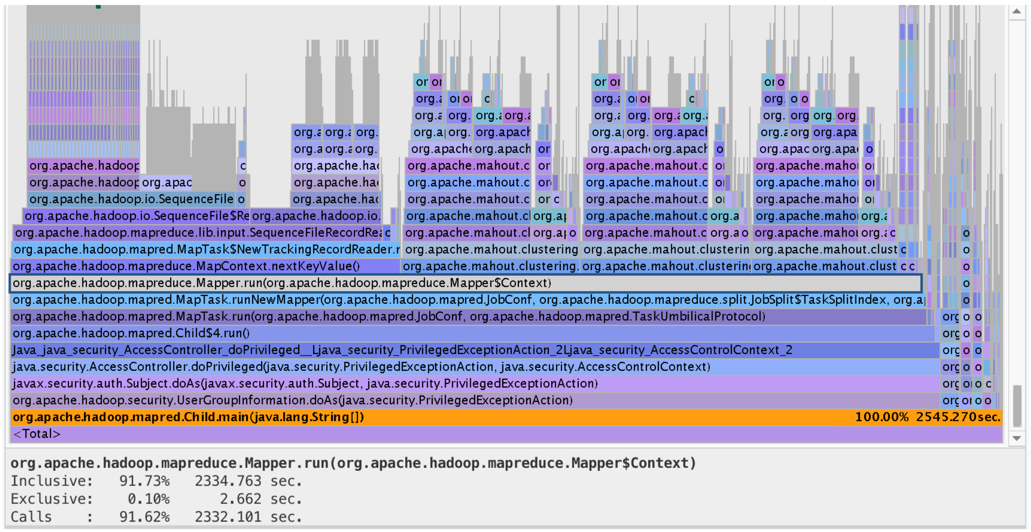
The metrics displayed in the Source view can be changed or reorganized. See the Help menu for details.

For detailed information about the content of the Source view, see "Performance Analyzer Source View Layout" on page 233.

Flame Graph View

The ame Graph view shows the same data as the Call Tree view, but in a graphical format. Call stacks climb vertically while the width of each frame is proportional to the selected inclusive metric. As a result, wider frames indicate hotter call paths. Frames are colored according to their function names. See the following screenshot as an example.

FIGURE 5 Flame Graph View in Performance Analyzer


org.apache.hadoop.mapreduce.lib.input.SequenceFileRecordRea
org.apache.hadoop.mapred.MapTask$NewTrackingRecordReader.r
org.apache.hadoop.mapreduce.MapContext.nextKeyValue()
org.apache.hadoop.mapreduce.Mapper.run(org.apache.hadoop.mapreduce.Mapper$Context)
org.apache.hadoop.mapred.MapTask.runNewMapper(org.apache.hadoop.mapred.JobConf, org.apache.hadoop.mapreduce.split.JobSplit$TaskSplitIndex, org.a
org.apache.hadoop.mapred.MapTask.run(org.apache.hadoop.mapred.JobConf, org.apache.hadoop.mapred.TaskUmbilicalProtocol)
org.apache.hadoop.mapred.Child$4.run()
Java_java_security_AccessController_doPrivileged__Ljava_security_PrivilegedExceptionAction_2Ljava_security_AccessControlContext_2
java.security.AccessController.doPrivileged(java.security.PrivilegedExceptionAction, java.security.AccessControlContext)
javax.security.auth.Subject.doAs(javax.security.auth.Subject, java.security.PrivilegedExceptionAction)
org.apache.hadoop.security.UserGroupInformation.doAs(java.security.PrivilegedExceptionAction)
org.apache.hadoop.mapred.Child.main(java.lang.String[]) 100.00% 2545.270sec.
<Total>

```
org.apache.hadoop.mapreduce.Mapper.run(org.apache.hadoop.mapreduce.Mapper$Context)
Inclusive:    91.73%   2334.763 sec.
Exclusive:     0.10%      2.662 sec.
Calls    :    91.62%   2332.101 sec.
```

While both the Call Tree and the me Graph can show the full tree starting from `<Total>`, the ame Graph can zoom in on a partial tree from a selected function. To see when a call path was sampled, filter by the desired call path, then open the Timeline view.

For more information on the ame Graph view, see the Help topic in Performance Analyzer.

Call Tree View

The Call Tree view displays a dynamic call graph of the program as a tree, with each function call shown as a node that you can expand and collapse. An expanded function node shows all the function calls made by the function, plus performance metrics for those function calls.

When you select a node, the Selection Details window displays metrics for the function call and its callees. The percentages given for attributed metrics are the percentages of the total program metrics. The default root of the tree is `<Total>`, which is not a function but represents 100% of the performance metrics of all the functions of the program.

Use the Call Tree view to see details of specific call traces and analyze which traces have the greatest performance impact. You can navigate through the structure of your program, searching for high metric values.

Tip - To easily find the branch that is consuming the most time, right-click any node and select Expand Hottest Branch.

To set a predefined filter for the selected branch or selected functions, right-click in the Call Tree view to open a context menu. By filtering in this way you can screen out data in all the Analyzer views for areas you are not interested in.

Callers-Callees View

The Callers-Callees view shows the calling relationships between the functions in your code, along with performance metrics. The Callers-Callees view enables you to examine metrics for code branches in detail by building call stack fragments one call at a time.

The view shows three separate panels: the Callers panel at the top, the Stack Fragment panel in the center, and the Callees panel at the bottom. When you first open the Callers-Callees view, the function in the Stack Fragment panel is the function that you selected in one of the other Analyzer views, such as the Function view or Source view. The Callers panel lists functions that call the function in the Stack Fragment panel, and the Callees panel lists functions that are called by the function in the Stack Fragment panel.

You can construct a call stack fragment around the center function, one call at a time, by adding callers or callees to the call stack.

To add a call to the stack fragment, double-click a function in the Callers pane or Callees pane, or select a function and click the Add button.

To remove a function call, double-click the function at the top or bottom of the call stack fragment, or select the top or bottom function and click Remove.

Tip - To perform the Add and Remove tasks through the context menu, right-click a function and select the appropriate command.

To set a function as the head (top), center, or tail (bottom) of the call stack fragment, select the function and click Set Head, Set Center, or Set Tail. This new ordering causes other functions currently in the call stack fragment to move to the Callers area or Callees area to their appropriate location in relation to the new location of the selected function in the stack fragment.

Use the Back and Forward buttons located above the Stack Fragment panel to go through the history of your changes to the call stack fragment.

As you add and remove functions in the stack fragment, the metrics are computed for the entire fragment and displayed next to the last function in the fragment.

You can select a function in any panel of the Callers-Callees view and then right-click to open a context menu and select filters. The data is filtered according to your selection in this view and all the Analyzer data views. See the online help for details about using context filters.

The Callers-Callees view shows attributed metrics:

- For the call stack fragment in the Stack Fragment panel, the attributed metric represents the exclusive metric for that call stack fragment.
- For the callees, the attributed metric represents the portion of the callee's metric that is attributable to calls from the call stack fragment. The sum of attributed metrics for the callees and the call stack fragment should add up to the metric for the call stack fragment.
- For the callers, the attributed metrics represent the portion of the call stack fragment's metric that is attributable to calls from the callers. The sum of the attributed metrics for all callers should also add up to the metric for the call stack fragment.

For more information about metrics, see “Function-Level Metrics: Exclusive, Inclusive, Attributed, and Static” on page 39.

Index Objects Views

Each Index Objects view shows the metric values from data attributed to various index objects, such as Threads, CPUs, and Seconds. Inclusive and Exclusive metrics are not shown, because Index objects are not hierarchical. Only a single metric of each type is shown.

Several Index Objects views are predefined: Threads, CPUs, Samples, Seconds, Processes, and Experiment IDs. These views are described separately below.

You can also define a custom index object. Click on the Add Custom View button in the Settings dialog box, the set the values for the object in the Add Index Objects dialog box.

Threads View

The Threads view shows a list of threads and their metrics. The threads are represented by a Process and Thread pair and show the Total CPU time by default. Other metrics might also be displayed by default if the metrics are present in the loaded experiments. The Threads view is not displayed by default. You can select it from the Views menu.

You can use the filter button to filter the data shown in this and Performance Analyzer views.

CPUs View

The CPUs view shows a list of CPUs that processed the target application's run, along with their metrics. The CPUs are represented by a CPU number and show the Total CPU time by default. Other metrics might also be displayed by default if the metrics are present in the loaded experiments. If the CPUs view is not visible you can select it from the Views menu.

You can use the filter button to filter the data shown in this and Performance Analyzer views.

Samples View

The Samples view shows a list of sample points and their metrics, which reflect the microstates recorded at each sample point in the loaded experiments. The Samples are represented by Sample numbers and show the Total CPU time by default. Other metrics might also be displayed if you selected them in the Overview panel or in the Settings dialog box. If the Samples view is not visible you can select it from the Views menu.

You can use the filter button to filter the data shown in this and Performance Analyzer views.

For more information on sample points, see the Performance Analyzer Help topic Sample Points.

Seconds View

The Seconds view shows each second of the program run that was captured in the experiment, along with metrics collected in that second. The Seconds view differs from the Samples view in that it shows periodic samples that occur every second beginning at 0 and the interval cannot be changed. The Seconds view lists the seconds of execution with the Total CPU time by default. Other metrics might also be displayed if the metrics are present in the loaded experiments. If you have selected other metrics in the Overview or by using the Settings dialog, those metrics are also displayed.

You can use the filter button to filter the data shown in this and Performance Analyzer views.

Processes View

The Processes view shows a list of processes that were created by your application, along with their metrics. The Processes are represented by process ID (PID) numbers and show the Total CPU time metric by default. Other metrics might also be displayed if the metrics are present in the loaded experiments. If you have selected other metrics in the Overview or by using the Settings dialog, those metrics are also displayed.

The Processes view enables you find the processes that used the most resources. If there is a particular set of processes that you want to isolate and explore using other views, you can filter out other processes using the filters available in the context menu.

Experiment IDs View

The Experiment IDs view shows a list of processes that were created by your application, along with their metrics. The Experiment IDs are represented by process ID (PID) numbers and show the Total CPU time metric by default. Other metrics might also be displayed if the metrics are present in the loaded experiments. If you have selected other metrics in the Overview or by using the Settings dialog, those metrics are also displayed. The metrics values reflect the microstates recorded at each sample point in the loaded experiments. The values reflect the value or percentage of the metrics that were recorded in each of the loaded experiments.

MemoryObjects Views

Each MemoryObjects view shows the metric values for dataspace metrics attributed to the various memory objects such as pages. If one or more of the loaded experiments contains a dataspace profile, you can select the memory objects for which you want to display views in the Views tab of the Settings dialog box. Any number of MemoryObjects views can be displayed.

Various MemoryObjects views are predefined. Memory objects are predefined for virtual and physical pages with names such as Vpage_8K, Ppage_8K, Vpage_64K, and so on. You can also define a custom memory object. Click the Add Custom Object button in the Settings dialog box, then set the values for the object in the Add Memory Objects dialog box.

DataLayout View

The DataLayout view shows the annotated data object layouts for all program data objects with data-derived metric data. The view is applicable only to experiments that include dataspace profiling, which is an extension of hardware counter overflow profiling. See "Dataspace Profiling and Memoryspace Profiling" on page 201 for more information.

The layouts appear in the view sorted by the data sort metrics values for the structure as a whole. The view shows each aggregate data object with the total metrics attributed to it, followed by all of its elements in offset order. Each element, in turn, has its own metrics and an indicator of its size and location in 32–byte blocks.

To display the DataLayout view, select it in the Views tab of the Settings dialog box (see "Views Settings" on page 140). As with the DataObjects view, you can make the DataLayout view visible only if one or more of the loaded experiments contains a dataspace profile.

To select a single data object, click that object.

To select several objects that are displayed contiguously in the view, select the first object, then press the Shift key while clicking the last object.

To select several objects that are not displayed contiguously in the view, select the first object, then select the additional objects by pressing the Ctrl key while clicking each object.

DataObjects View

The DataObjects view shows the list of data objects with their metrics. The view applies only to experiments that include dataspace profiling, which is an extension of hardware counter overflow profiling. See "Dataspace Profiling and Memoryspace Profiling" on page 201 for more information.

You display the view by selecting it in the Views tab of the Settings dialog box (see "Views Settings" on page 140). You can make the DataObjects view visible only if one or more of the loaded experiments contains a dataspace profile.

The view shows hardware counter memory operation metrics against the various data structures and variables in the program.

To select a single data object, click that object.

To select several objects that are displayed contiguously in the view, select the first object, then press Shift while clicking the last object.

To select several objects that are not displayed contiguously in the view, select the first object, then select the additional objects by pressing Ctrl while clicking each object.

I/O View

Use the I/O view to identify the I/O patterns in your application and pinpoint the I/O bottlenecks that impact its performance. The I/O view is available if you profiled your application for I/O tracing data.

You can aggregate the I/O data according to one of the following options:

File Name	Shows a table of the files accessed by the program. Each row represents a file. The metrics for one row represent the aggregated I/O statistics for all accesses of the file.
File Descriptor	Shows a table of file descriptors for files accessed by the program. Each row represents a single instance of a file being opened. If the same file is opened multiple times the table contains multiple rows for the same file. The metrics for one row apply to a single instance of the file opening.
Call Stack	Shows a table of call stacks listed with arbitrary stack numbers. Click a stack to see the function calls in the stack displayed in the Call Stack panel. The metrics apply to the selected call stack.

Heap View

The Heap view shows a list of call stacks that have memory allocation metrics that indicate possible memory leaks. The call stacks are identified by arbitrary stack numbers. One call stack is labeled to indicate peak memory usage.

Click a call stack to display the metrics details in the Selection Details panel and display the call stack's function calls in the Call Stack panel. You can double-click a function in the Call Stack panel to see the source. You can also set filters to filter out the selected call stacks or to filter out the unselected call stacks. You can select the Heap view in the Views tab of the Settings dialog box only if one or more of the loaded experiments contains heap trace data. The bottom panel of the Heap view shows detailed data for the `<Total>` pseudo function which represents the full target application.

Data Size View

The Data Size view is available for experiments that contain data that has a size element such as a number of bytes. Experiments that include heap tracing, I/O tracing, or MPI tracing have a Data Size view.

The Data Size view organizes the data into ranges of data sizes and calculates the metrics for the events whose data falls into a given range. Data without a size element is attributed to data size 0.

You can use the Data Size view to filter the data. For example, in an experiment that contains heap tracing data, you could select a size range line that has high metrics for Bytes Leaked and add the filter Include only events with selected items. When you go to other data views, the data is filtered to show only events that produced memory leaks of that size range you selected.

Duration View

The Duration view is available for experiments that contain data that has a duration. Experiments that include I/O tracing data, MPI tracing, heap tracing, and synchronization tracing data have a Duration view.

The Duration view organizes the data into ranges of duration time and calculates the metrics for the events whose data falls into each range of duration time. The duration of the function call is recorded for I/O tracing, MPI tracing, and synchronization tracing. For heap tracing, the duration is the time between allocation and freeing of memory. Data without a duration element is attributed to duration 0.

You can use the Duration view to filter the data. For example, in an experiment that contains heap tracing data, you could select a duration range line that has high metrics for Bytes Allocated and add the filter Include only events with selected items. When you go to other data views, the data is filtered to show only events whose duration matched the range you selected and might reveal memory allocations that are longer duration than expected.

OpenMP Parallel Region View

The OpenMP Parallel Region view is applicable only to experiments that were recorded with the OpenMP 3.0 collector, for programs that use OpenMP tasks compiled with Oracle Developer Studio compilers. See “Limitations on OpenMP Profiling” on page 62 for more information.

The view lists all parallel areas encountered during the program's execution along with metric values computed from the same profiling data. Exclusive metrics are computed for the current parallel region. Inclusive metrics reflect nested parallelism. They are attributed to the current parallel region, and the parent parallel region from which it was created. The attributions go further on recursively up to the topmost Implicit OpenMP Parallel Region, representing the serial execution of the program (outside any parallel region). If there are no nested parallel regions in a program, the exclusive and inclusive metrics have the same values.

If a function containing a parallel region is called many times, all instances of the parallel region will be aggregated together and presented as one line item in the corresponding view.

The view is useful for navigation. You can select an item of interest, such as the parallel region with the highest OpenMP Wait time, and analyze its source or select a context filter to include only the data related to the selected item. You can then analyze how the data is represented by other program objects using other views: Functions, Timeline, Threads, and so on.

OpenMP Task View

The OpenMP Task view shows the list of OpenMP tasks with their metrics. The options in this view are applicable only to experiments that were recorded with the OpenMP 3.0 collector, for programs that use OpenMP tasks compiled with Oracle Developer Studio compilers. See "Limitations on OpenMP Profiling" on page 62 for more information.

The view lists tasks encountered during the program's execution, along with metric values computed from the profiling data. Exclusive metrics apply to the current task only. Inclusive metrics include metrics for OpenMP tasks plus those of their child tasks, with their parent-child relationship established at the task creation time. The OpenMP Task from Implicit Parallel Region represents the serial execution of the program.

If a function containing a task is called many times, all instances of the parallel region will be aggregated together and presented as one line item in the corresponding view.

The view is useful for navigation. You can select an item of interest, such as the task with the highest OpenMP Wait time, analyze its source by clicking the Source view. You can also right-click to select a context filter to include only the data related to the selected item, You can then analyze how it's represented by other program objects using other views: Functions, Timeline, Threads, and so on.

Lines View

The Lines view shows a list consisting of source lines and their metrics.

Source lines are labeled with the function from which they came and the line number and source file name. If no line-number information is available for a function, or if the source file for the function is not known, all of the function’s program counters (PCs) appear aggregated into a single entry for the function in the lines display. PCs from functions that are from load-objects whose functions are hidden appear aggregated as a single entry for the load-object in the lines display. Selecting a line in the Lines view shows all the metrics for a given line in the Selection Details window. Selecting the Source or Disassembly view after selecting a line from the Lines view positions the display at the appropriate line.

PCs View

The PCs view lists program counters (PCs) and their metrics. PCs are labeled with the function from which they came and the offset within that function. PCs from functions that are from load-objects whose functions are hidden appear aggregated as a single entry for the load-object in the PCs display. Selecting a line in the PCs view shows all the metrics for that PC in the Summary tab. Selecting the Source view or Disassembly view after selecting a line from the PCs view positions the display at the appropriate line.

See the section “Call Stacks and Program Execution” on page 203 for more information about PCs.

Disassembly View

The Disassembly view shows a disassembly listing of the object file containing the selected function, annotated with performance metrics for each instruction. You might need to select Machine from the View Mode list in the toolbar to see the disassembly listing.

Interleaved within the disassembly listing is the source code, if available, and any compiler commentary chosen for display. The algorithm for finding the source file in the Disassembly view is the same as the algorithm used in the Source view.

Just as with the Source view, index lines are displayed in Disassembly view. But unlike with the Source view, index lines for alternate source contexts cannot be used directly for navigation purposes. Also, index lines for alternate source contexts are displayed at the start of where the `#included` or inlined code is inserted, rather than just being listed at the beginning of the Disassembly view.

Code that is `#included` or inlined from other files shows as raw disassembly instructions without interleaving the source code. However, placing the cursor on one of these instructions and selecting the Source view opens the source file containing the `#included` or inlined code.

Selecting the Disassembly view with this file displayed opens the Disassembly view in the new context, thus displaying the disassembly code with interleaved source code.

You can set the classes of commentary that are displayed in the Settings dialog box. The default classes can be set in a `.er.rc` defaults file by clicking the Save button in the dialog box.

Performance Analyzer highlights hot lines, which are lines with metrics that are equal to or exceed a metric-specific threshold, to make it easier to find the important lines. You can set the threshold in the Settings dialog box.

As with the Source view, yellow navigation markers are shown in a margin next to the scrollbar on the right for each source line with metrics. Non-zero metrics that are below the hot threshold are not highlighted but are flagged with yellow navigation markers. To quickly navigate to source lines with metrics, you can click the yellow markers in the right margin to jump to the lines with metrics. You can also right-click the metrics themselves and select an option such as Next Hot Line or Next Non-Zero Metric Line to jump to the next line with metrics.

For detailed information about the content of the Disassembly view, see "Annotated Disassembly Code" on page 240.

Source/Disassembly View

The Source/Disassembly view shows the annotated source in an upper pane, and the annotated disassembly in a lower pane. The panes are coordinated so that when you select lines in one pane the related lines in the other pane are also selected. The view is not visible by default.

Races View

The Races view shows a list of all the data races detected in a data-race experiment. You can click a data race to see details about it in the Race Detail window on the right panel. For more information, see *Oracle Developer Studio 12.6: Thread Analyzer User's Guide*.

Deadlocks View

The Deadlocks view shows a list of all the deadlocks detected in a deadlock experiment. Click a deadlock to see details about it in the Deadlock Details window in the right panel. For more information, press F1 to view the help and see *Oracle Developer Studio 12.6: Thread Analyzer User's Guide*.

Dual-Source View

The Dual-Source view shows the two source contexts involved in the selected data race or deadlock. The view is shown only if data-race-detection or deadlock experiments are loaded. See *Oracle Developer Studio 12.6: Thread Analyzer User's Guide* for more information.

Statistics View

The Statistics view shows totals for various system statistics summed over the selected experiments and samples. The totals are followed by the statistics for the selected samples of each experiment. For information on the statistics presented, see the `getrusage`(3C) and `proc` (4) man pages.

Experiments View

The Experiments view is divided into two panels. The top panel contains a tree that includes nodes for the load objects in all the loaded experiments, and for each experiment loaded. When you expand the Load Objects node, a list of all load objects is displayed with various messages about their processing. When you expand the node for an experiment, two areas are displayed: a Notes area and an Info area.

The Notes area displays the contents of any notes file in the experiment. You can edit the notes by typing directly in the Notes area. The Notes area includes its own toolbar with buttons for saving or discarding the notes and for undoing or redoing any edits since the last save.

The Info area contains information about the experiments collected and the load objects accessed by the collection target, including any error messages or warning messages generated during the processing of the experiment or the load objects.

The bottom panel lists error and warning messages from the Performance Analyzer session.

Inst-Freq View

The Inst-Freq (instruction-frequency) view shows a summary of the frequency with which each type of instruction was executed in a count-data experiment, which is collected with `collect -c`. The view also shows data about the frequency of execution of load, store, and floating-point instructions. In addition, the view includes information about annulled instructions and instructions in a branch delay slot.

MPI Timeline View

The MPI Timeline view shows a set of horizontal bars, one for each process in the MPI experiment, with diagonal lines connecting them that indicate messages. Each bar has regions colored according to the MPI function they are in, or indicating that the process is not within MPI (that is, it is elsewhere in the application code).

Selecting a region of a bar or a message line shows detailed information about the selection in the MPI Timeline Controls window.

Dragging the mouse causes the MPI Timeline view to zoom in on the horizontal (time) axis or the vertical (process) axis, depending on the predominant direction of the drag.

You can print an image of the MPI Timeline to a `.jpg` file. Choose File → Export and select Export as JPEG.

MPI Timeline Controls

The MPI Timeline Controls window supports zoom, pan, event-step, and filtering for the MPI Timeline view. It includes a control to adjust the percentage of MPI messages shown on MPI Timeline.

Filtering causes data outside the current field of view to be eliminated from the data set shown in the MPI Timeline view and the MPI Chart view. Click the Filter button to apply a filter. Use the back-filter button to undo the last filter and the forward-filter button to reapply a filter. Filters are shared between the MPI Timeline view and the MPI Chart view but are not applied to other data views.

The message slider can be adjusted to control the percentage of messages displayed. When you select less than 100%, priority is given to the most costly messages. Cost is defined as the time spent in the message's send and receive functions.

The MPI Timeline Controls window also shows the details for a function or message selection from the MPI Timeline view.

MPI Chart View

The MPI Chart view shows charts of the MPI tracing data displayed in the MPI Timeline view. It displays plots of data concerning MPI execution. Changing the controls in the MPI Chart view and clicking Redraw causes a new chart to be displayed. Selecting an element from a chart shows more detailed information about that element in the MPI Chart Controls view.

Dragging the mouse causes the MPI Chart view to zoom in on the rectangular area defined by the drag.

You can print an image of the MPI chart to a `.jpg` file. Choose File → Export and select Export as JPEG.

MPI Chart Controls

The MPI Chart Controls window has a set of drop-down lists to control the type of chart, the parameters for the X and Y axes, and the Metric and Operator used to aggregate the data. Clicking Redraw causes a new graph to be drawn.

Filtering causes data outside the current field of view to be eliminated from the data set shown in the MPI Timeline view and MPI Chart view. To apply a filter, click the Filter button. Click the back-filter button to undo the last filter; click the forward-filter button to reapply a filter.

The MPI Chart Controls window is also used to show the details for a selection from the MPI Chart view.

Setting Library and Class Visibility

By default, Performance Analyzer shows function data for the target program and all shared libraries and classes used by the program. You can hide the function data for any library or class using the Library and Class Visibility dialog box.

To open the dialog box, choose Tools > Library Visibility or click the Library Visibility toolbar button.

The Library and Class Visibility dialog box lists all shared libraries and classes in the experiment. For each item listed, you can choose one of the following visibility levels:

Functions	All functions of the library or class are made visible. Where applicable, metrics are shown for each function.
API	Only the functions that represent calls into the library or class are shown. Calls below those functions, whether within that library or into other libraries, including callbacks, are not shown.

Library	Only the name of the library or class is made visible; all internal functions are hidden. A library's metrics will reflect the aggregation of metrics incurred by internal functions. Selecting the Library check box for all entries in the list will allow you to perform analysis by library or class.

The Filters fields enable you to update the visibility settings for a subset of libraries and classes. For programs that load a large number of libraries, the list can be quite large. These filters act only on the dialog and are not related to the data view filters.

When you set library visibility, metrics corresponding to hidden functions are still represented in some form in all displays. This contrasts with data view filters, which remove data from displays. For information on tasks you can perform in this dialog, see the Performance Analyzer Help.

Filtering Data

When you open an experiment you see all the profiling data from your program. Filtering enables you to temporarily remove uninteresting data from view so you can focus on a specific area or characteristic of your program.

A filter that you apply in one view affects all views. For example, you can specify a time period filter in the Timeline view so other views such as Functions only show metrics pertaining to the filtered time period. Select one or more items in a view and then select filters one at a time to specify the data that you want to include in the view.

You can filter in several ways:

- Click the Filter button to open a list of filters that can be applied for the selected items in the current data view.
- Right-click an item in a data view or press Shift-F10 while it is selected, and then select a filter to apply.
- Use the Filters panel in the lower left corner of Performance Analyzer to see the filters you have applied and add or remove them.

You can combine filters to display metrics from highly specific areas of your program's run. For example you could apply a filter in the Functions view and a filter in the Timeline view to focus on call stacks that include a particular function during a specific period of time in the program's run.

When you use filters, the data is filtered in all Performance Analyzer views except the MPI Timeline, which has a separate filtering mechanism that does not interact with the other data views.

Experienced users of Performance Analyzer can also use the Advanced Custom Filters dialog box to edit filter expressions to create custom filters to precisely define the data to be displayed.

Note - The filters described here are independent of the MPI filtering described in "MPI Timeline Controls" on page 130 and "MPI Chart Controls" on page 131. These filters do not affect the MPI Timeline view and the MPI Chart view.

Using Filters

Filters are available in most data views in Performance Analyzer. You access them using the Filter button on the toolbar or in the Active Filters panel, or by right-clicking with the mouse or by pressing Shift-F10 on the keyboard. When you add a filter, the data is immediately filtered.

In general, you use filters by selecting one or more items in the view that you want to focus on, and selecting the appropriate filter. For most views the filters enable you to include or *not* include the data that meets the criteria named in the filter. This enables you to use the filters to either focus on data from a particular area of your program, or exclude data from a particular area.

Some ways you can use filters include:

- Add multiple filters to narrow down the data. The filters are combined in a logical `AND` relationship, which requires the data to match all of the filters.
- Add a filter in one view and then examine the filtered data in another view. For example, in the Call Tree view you can find the hottest branch, select "Add Filter: Include only stacks containing the selected branch", and then go to the Functions view to see metrics for the functions called in that code branch.
- Add multiple filters from multiple views to create a very specific set of data.
- Use filters as a basis for creating advanced custom filters. See "Using Advanced Custom Filters" on page 133.

Using Advanced Custom Filters

When you add filters in Performance Analyzer data views, filter expressions are generated and are immediately applied to filter the data. The generated filter expressions are visible in the Advanced Custom Filter dialog box. Experienced users can use these generated filter expressions as a beginning point for creating customized filters.

To create a custom filter:

1. Open the Advanced Custom Filter dialog box by doing one of the following:

- Click the Filter button and select Add Filter: Advanced Custom Filter
- Choose Tools ⇒ Filters ⇒ Add Filter: Advanced Custom Filter

2. Click in the Filter Specification text box and edit the filters. See below for more information about the filters.
3. Use the arrow buttons to undo or redo edits if necessary.
4. Click OK to filter the data according to the filter expressions and close the dialog box.

The Filter Specification panel shows the filter expressions for filters you previously applied by selecting them in Performance Analyzer data views. You can edit these filters, and use the arrow buttons at the top to undo and redo your edits. You can also use Ctrl-Z to undo and Shift-Ctrl-Z to redo as you would in a text editor. The filters only affect the data views when you click OK.

Place each new filter on a new line beginning with `&&` the logical AND operator. Experiment data must match the first filter AND the second filter AND the third filter, and so on, in order to be displayed.

You can change `&&` to `||` if you want data to match the first filter OR the second filter, for example.

Filter expressions use standard C relational operators (==, >=, &&, `||`, and so on) along with keywords that are specific to the experiment. The keywords that you can use in your experiment are shown in the Keywords panel of the Advanced Custom Filters dialog box.

Search the Performance Analyzer help for more information about filter keywords and filter expressions.

The filter expression syntax is the same as that used for filtering with `er_print`. See "Expression Grammar" on page 185 for information about filter expressions.

Using Labels for Filtering

Labels are names you can assign to a portion of an experiment. Using the `er_label` command, you can assign a label name to a period of time in an experiment and the label persists with the experiment. You can use the label to filter the experiment data with the `er_print` command or Performance Analyzer to include or exclude the data collected during the labeled time period.

See "Labeling Experiments" on page 254 for information about how to use the `er_label` utility to create labels.

In Performance Analyzer you can filter data from the labeled time period in the Advanced Custom Filter dialog box. Type the label name in the Filter Specification panel and click Apply to filter the data specified by the label. You do not need to use any numerical comparison because the label acts as a nickname for a filter expression that uses a numerical comparison with the `TSTAMP` keyword. You can combine the label with other filters in the Filter Specification panel by adding it on a separate line preceded by `&&`.

You can see if there are labels assigned to an experiment that is open in Performance Analyzer in the Keywords panel of the Advanced Custom Filters dialog box.. You can also use the `er_print -describe` command to see the same information. Labels are listed first in the display and include the actual filter expression with the `TSTAMP` keyword that is implemented by the label.

After applying a label filter, you can click the Timeline view to see data is removed in the intervals that were defined by the label. The data is also filtered in other data views that support filtering.

Profiling Applications From Performance Analyzer

You can profile an application by using the `collect` command from a terminal window or using Performance Analyzer.

To profile an application in Performance Analyzer do one of the following:

- Click Profile Application in the Welcome screen.
- Click the Profile Application toolbar button.
- Choose File → Profile Application.
- Run the `analyzer` command and specify the target program and its arguments on the command line.

Each of these methods open the Profile Application dialog box. Press F1 to view help information about the dialog.

The options in the Profile Application dialog correspond to the options available in the `collect` command, as described in Chapter 3, "Collecting Performance Data".

Target Program is the only required entry if you want to use the default profiling options and collect only clock profiling data. Otherwise, you can specify experiment options in the General tab, and select the types of data you want to collect in the Data to Collect tab.

If you click the Preview Command button you can see the `collect` command that would be used when you click the Run button. Then simply click Run to start profiling, collecting data, and creating an experiment.

The target program's output is shown by default in a separate terminal window that is opened by Performance Analyzer. If you close the Profile Application dialog while an experiment is in progress, the experiment continues. If you reopen the dialog, it shows the experiment in progress, as if it had been left open during the run. If you attempt to exit Performance Analyzer while an experiment is in progress, a dialog box asks if you want the run terminated or allowed to continue.

To stop the experiment, click Terminate. You must confirm that you want to stop the experiment.

You can also profile a running process, as explained in the next section, and profile the kernel, as explained in Chapter 9, “Kernel Profiling”.

Profiling a Running Process

On Oracle Solaris, you can collect data from any running process in Performance Analyzer or from the command line. On Linux, profiling a running process works reliably on single-threaded applications only. Because the JVM is multithreaded, you cannot profile Java applications on Linux.

If you want to profile a running process from the command line, see the `collect`(1) man page.

To profile a running process in Performance Analyzer do one of the following:

- Click Profile Running Process in the Welcome screen.
- Choose File → Profile Running Process.

Select the process you want to profile in the Profile Running Process dialog box and click Run if you want to use the default options. Otherwise, you can specify experiment options in the General tab, and select the types of data you want to collect in the Data to Collect tab.

Press F1 while the dialog is open to view the help for the dialog.

The Output tab displays output from the Collector and any output from your process. Click Terminate when you want to stop profiling. Performance Analyzer prompts you to open the experiment.

Comparing Experiments

You can load multiple experiments or experiment groups simultaneously in Performance Analyzer. By default, when multiple experiments on the same executable are loaded, the data is aggregated and presented as if it were one experiment. You can also look at the data separately so you can compare the data in the experiments.

To compare two experiments in Performance Analyzer, click the Compare Experiments icon in the toolbar and select two experiments to compare.

Most data views support comparing experiments. In comparison mode, the data from the experiments or groups is shown in adjacent columns. The columns are shown in the order of the loading of the experiments or groups, with an additional header line giving the experiment or group name.

Setting Comparison Style

Use the style buttons in the Compare Status panel. For the Comparison Style, you can specify one of the following:

Absolute Values	Shows the metrics values for all loaded experiments.
Deltas	Shows the +/- difference between metrics for the baseline experiment and the other loaded experiments.
Ratios	Shows the difference between metrics for the baseline experiment and the other loaded experiments as a ratio. For example, a comparison experiment metric might display as `x0.994` to indicate its value relative to the base experiment.

For tips and more information about the Compare Status panel, see the Performance Analyzer help.

Using Performance Analyzer Remotely

You can use Performance Analyzer remotely between servers that have the Oracle Developer Studio tools installed, or even on a desktop client where Oracle Developer Studio cannot be installed.

Using Performance Analyzer on a Desktop Client

You can install a special version of Performance Analyzer on a desktop client system and connect to a remote server where the tools are installed.

Requirements of the client system:

- Operating system must be Mac OS X, Windows, Linux, or Oracle Solaris.

- The version of the Performance Analyzer must match the version of Oracle Developer Studio tools installed on the remote system.
- Java 1.7 or 1.8 must be in the user's path.

Requirements of the remote system:

- Operating system must be Oracle Solaris or Linux.
- Secure Shell (SSH) daemon, sshd must be running.
- Oracle Developer Studio software must be accessible on the remote host and you need to know the path to the software.
- You must have a user account on the host.

A version of Performance Analyzer for use on a client system is available in a tar file that you can copy to any system including Mac OS X or Windows machines. This version is known as the remote Performance Analyzer client, and enables you to use Performance Analyzer on any system that has Java 1.7 or Java 1.8 available.

The remote Performance Analyzer client is located in the Oracle Developer Studio installation at */install-dir*`/lib/analyzer/RemoteAnalyzer.tar`.

Before you can use Performance Analyzer on a desktop client you must install the special remote version on the client as described in the following task.

▼ How to Use the Remote Performance Analyzer on a Client

1. **Copy the `RemoteAnalyzer.tar` file to the desktop client system where you want to run it.**

2. **Extract `RemoteAnalyzer.tar` using a file extraction utility or command.**

   Note that on Windows you might need to install an application such as WinZip or 7-Zip to extract the file.

   The extracted `RemoteAnalyzer` directory contains scripts for Windows, Mac OS X, Linux and Solaris, and a `README.txt` file.

3. **Execute the script for the system you are using.**

Windows	Double-click the `AnalyzerWindows.bat` file in the `RemoteAnalyzer` directory.
Mac	Run `AnalyzerMacOS.command` file in the `RemoteAnalyzer` directory.
Linux	Run the `AnalyzerLinux.sh` script in a terminal window.

Oracle Solaris	Run the `AnalyzerSolaris.sh` script in a terminal window.

The Performance Analyzer window opens to show the Welcome screen with only the features that work remotely enabled. For more information, see the`RemoteAnalyzer/README.txt` file.

Connecting to a Remote Host in Performance Analyzer

You can connect to a remote host in the following ways:

- In the Welcome view, click Connect To Remote Host.
- Choose File > Connect To Remote Host.
- Click the Remote Host status message at the bottom of the Performance Analyzer window.

Press F1 in the Connect to Remote Host dialog box for information about answering the prompts.

When the connection is completed, the status area at the bottom of the main Performance Analyzer window shows that you are connected to the host. Note that while you are connected to the remote host, Performance Analyzer's file browser automatically accesses the file system of the remote host to open experiments.

Configuration Settings

You can control the presentation of data and other configuration settings using the Settings dialog box. To open this dialog box, click the Settings button in the toolbar or choose Tools → Settings.

The Settings are organized in the following categories:

- “Views Settings” on page 140
- “Metrics Settings” on page 141
- “Timeline Settings” on page 141
- “Source/Disassembly Settings” on page 143
- “Call Tree Settings” on page 143
- “Formats Settings” on page 144
- “Search Path Settings” on page 145
- “Pathmaps Settings” on page 146

The OK button applies the changes you made for the current session, and closes the dialog box. The Apply button applies the changes for the current session, but keeps the dialog box open so you can make more changes. The Close button closes the dialog box without saving or applying changes.

The Export button opens the Export Settings dialog which you can use to select which settings to export, and where to save them. Exported configuration settings can be applied to the experiment when you open it again in future Performance Analyzer sessions as well as the current session. You can also use configurations for other experiments. See "Performance Analyzer Configuration File" on page 146 for more information.

Views Settings

The Views settings panel lists the applicable data views for the current experiment.

Standard Views

Click the check boxes to select or deselect standard data views for display in Performance Analyzer.

Index Objects Views

Click the check boxes to select or deselect Index Object views for display. The predefined Index Object views include Threads, CPUs, Samples, Seconds, Processes.

To add a view for a custom index object, click the Add Custom View button to open the Add Index Object dialog. The index object name you specify must not already be defined, and it cannot match any existing command, or any Memory Object type. The name is not case-sensitive, and must be entirely composed of alphanumeric characters or the '_' character, and begin with an alphabetic character. The formula must follow the syntax described in "Expression Grammar" on page 185.

Index objects can also be created using the `er_print` command. See "Commands That Control Index Object Lists" on page 167

Memory Object Views

Click the check boxes to select or deselect predefined Memory Object views for display. These views are available when the experiment contains hardware counter profiling data.

Memory objects represent components in the memory subsystem, such as cache lines, pages, and memory banks. Memory objects are predefined for virtual and physical pages, for sizes of 8KB, 64KB, 512KB, and 4MB.

To add a view for a custom memory object, click the Add Custom Memory Object View button to open the Add Memory Object dialog box. The memory object name you specify must not already be defined and it cannot match any existing command or any Index Object type. The name is not case-sensitive, and must be entirely composed of alphanumeric characters or the '_' character, and begin with an alphabetic character. The formula must follow the syntax described in “Expression Grammar” on page 185.

Machine Model Files

You can load a file that defines Memory Objects for a specific SPARC system architecture. Select the system architecture of interest from the Machine Model drop down menu. Click Apply or OK and a new list of objects displays in the Memory Objects Views column. You can select from these views to display associated data. Search for "Machine Model" in the help for more information.

By default Performance Analyzer loads a machine model file that is appropriate for the machine on which an experiment was recorded. Machine model files can define both Memory Objects and Index Objects.

Metrics Settings

The Metrics settings enable you to choose the metrics that are displayed in most of the Analyzer tabs including Functions, Callers-Callees, Source, Disassembly, and others. Some metrics can be displayed in your choice of time or percentage, while others are displayed as a value. The list of metrics includes all metrics that are available in any of the experiments that are loaded.

For each metric, check boxes are provided for Time and Percentage, or Value. Select the check boxes for the types of metrics that you want Performance Analyzer to display. Click Apply to update views with the new metrics. The Overview also allows you to select metrics and is synchronized with the settings you make here. You can sort the metrics by clicking the column headers.

Note - You can only choose to display exclusive and inclusive metrics. Attributed metrics are always displayed in the Call Tree view if either the exclusive metric or the inclusive metric is displayed.

Timeline Settings

The Timeline settings enable you to specify the information displayed in the “Timeline View” on page 114.

Data Types

Select the kinds of data to display. The selection applies to all experiments and all display types. If a data type is not included in an experiment, the data type is not displayed in the settings as a selectable data type.

CPU Utilization Samples

Select to display a CPU Utilization Samples bar for each process. The Samples bar shows a graph summarizing the microstate information for each periodic sample.

Clock Profiling

Select to display a timeline bar of clock profiling data captured for each LWP, thread, CPU, or experiment. The bar for each item shows a colored call stack of the function that was executing at each sampled event.

HW Counter Profiling (keyword)

Select to display a timeline bar of hardware counter profiling data.

I/O Tracing

Select to display a timeline bar of I/O tracing data.

Heap Tracing

Select to display a timeline bar of heap tracing data.

Synchronization Tracing

Select to display a timeline bar of synchronization tracing call stacks.

Event States

Select to add a graph to each timeline bar to show the microstate for each event. Event Density - select to add a graph to each timeline bar to show when an event occurs.

Group Data By

Specify how to organize the timeline bars for each process - by LWP, thread, CPU, or for the overall process. You can also set the grouping using the Group Data list in the Timeline toolbar.

Stack Alignment

Specify whether the call stacks displayed in the timeline event markers are aligned on the leaf function or the root function. Select leaf if you want the last function called to be shown at the bottom of the stack. This setting does not affect the data presented in the Selection Details panel, which always displays the leaf function at the top.

Call Stack Magnification

Specify how many pixels should be used when displaying each function in a call stack. A value of three is the default. This setting, along with the timeline vertical zoom which controls the available space per row, determines whether or not deep call stacks will be truncated or fully displayed.

Source/Disassembly Settings

The Source/Disassembly settings enable you to select the information presented in the Source view, Disassembly view, and Source/Disassembly view.

Compiler Commentary

Select the classes of compiler commentary that are displayed in the Source view and the Disassembly view.

Hot Line Highlighting Threshold

The threshold for highlighting high-metric lines in the Source view and the Disassembly view. The threshold is the percentage of the largest metric value attributed to any line in the file whose source or disassembly is displayed. The threshold is applied to each metric independently.

Source Code

Display the source code in the Disassembly view. If you display source code in the Disassembly view, the compiler commentary is also displayed for the classes that are enabled.

Metrics for Source Lines

Display metrics for the source code in the Disassembly view.

Hexadecimal Instructions

Display instructions in hexadecimal in the Disassembly view.

Only Show Data of Current Function

Display metrics only for the instructions of the current function selected in another view. If you select this option, metrics are hidden for all other instructions.

Show Compiler Command-line Flags

Display the compiler command and options used to compile the target program. Scroll to the last line of the Source view to see the command line.

Show Function Beginning Line

Toggle function beginning line on or off.

Call Tree Settings

The Call Tree setting, Expand branches when percent of metric exceeds this threshold, sets the trigger for expanding branches in the Call Tree view. If a branch of the call tree uses the specified percentage or less of the metric, it is not expanded automatically when you select an expanding action such as Expand Branch or Expand All Branches. If it exceeds the percentage, it does expand.

Formats Settings

The Formats settings enable you to specify miscellaneous data view formatting.

Function Name Style

Specify whether you want function names to be displayed in long form, short form, or mangled form of C++ function names and Java method names.

Append SO name to Function name

Select the check box to append to a function or method name the name of the shared object in which the function or method is located.

View Mode

Set the initial value for the view mode toolbar setting, which is enabled only for Java experiments and OpenMP experiments. The view modes User, Expert, and Machine set the default mode for viewing experiments. You can switch the current view using the view mode list in the toolbar.

For Java experiments:

- User mode shows metrics for interpreted methods and any native methods called. The special function `<no Java call stack recorded >` indicates that the Java Virtual Machine (JVM) software did not report a Java call stack, even though a Java program was running.
- Expert mode shows metrics for interpreted methods and any native methods called, and additionally lists methods that were dynamically compiled by the JVM.
- Machine mode shows multiple JVM compilations as completely independent functions, although the functions will have the same name. In this mode, all functions from the JVM software are shown as such.

See "Java Profiling View Modes" on page 209 for more detailed descriptions of the view modes for Java experiments.

For OpenMP experiments:

- User mode shows reconstructed call stacks similar to those obtained when the program is compiled without OpenMP. Special functions with names of the form `<OMP-*>` are shown when the OpenMP runtime is performing certain operations.
- Expert mode shows compiler-generated functions representing parallelized loops, tasks, and so on, which are aggregated with user functions in User mode. Special functions

with names of the form `<OMP-*>` are shown when the OpenMP runtime is performing certain operations.

- Machine mode shows machine call stacks for all threads without any special `<OMP-*>` functions.

See "Overview of OpenMP Software Execution" on page 210 for more detailed descriptions of the view modes for OpenMP experiments.

For all other experiments, all three modes show the same data.

Comparison Style

Specify how you want to display data when comparing experiments. For example, a comparison experiment metric might display as x0.994 to indicate its value relative to the base experiment.

Absolute Values	Shows the metrics values for all loaded experiments.
Deltas	Shows the +/- difference between metrics for the baseline experiment and the other loaded experiments.
Ratios	Shows the difference between metrics for the baseline experiment and the other loaded experiments as a ratio.

Search Path Settings

The Search Path setting specifies the path used for finding the loaded experiment's associated source and object files for displaying annotated source data in the Source and Disassembly views. The search path is also used to locate the `.jar` files for the Java Runtime Environment on your system. The special directory name `$expts` refers to the set of current experiments, in the order in which they were loaded. Only the founder experiment is looked at when searching `$expts`, no descendant experiments are examined.

By default the search path is set to `$expts` and `.` (the current directory). You can add other paths to search by typing or browsing to the path and clicking Append. To edit paths in the list, select a path, edit it in the Paths field, and click Update. To change the search order, select a path in the list and click the Move Up/ Move Down buttons.

See "How the Tools Find Source Code" on page 231 for more information about how the search path is used.

Pathmaps Settings

The Pathmaps settings enable you to map the leading part of a file path from one location to another to help Performance Analyzer locate source files. A path map is useful for an experiment that has been moved from the original location it was recorded. When the source can be found Performance Analyzer can display annotated source data in the Source and Disassembly views.

From path	Type the beginning of the path to the source that was used in the experiment. You can find this path by viewing the Selection Details panel when the experiment is open in Performance Analyzer.
To path	Type or browse to the beginning of the path to the source from the current location where you are running Performance Analyzer. For example, if the experiment contains paths specified as `/a/b/c/d/sourcefile` and `soucefile` is now located in `/x`, you can use the Pathmaps setting to map `/a/b/c/d/` to `/x/`. Multiple path maps can be specified, and each is tried in order to find a file.

See "How the Tools Find Source Code" on page 231 for more information about how the path maps are used.

Performance Analyzer Configuration File

Performance Analyzer saves your configuration settings automatically when you exit the tool. When you open the same experiment again, it is configured as it was when you previously closed the experiment.

You can save some settings in a configuration file whose name ends in `config.xml` and apply the configuration file to any experiment when you open it from the Open Experiment dialog. You can save configurations in a location only for your use or save to a shared location for use by other users.

When you open an experiment, Performance Analyzer searches default locations for available configuration files and enables you to choose which configuration to apply to the experiment you are opening.

You can also export settings into a `.er.rc` file that can be read by `er_print` using Tools > Export Settings as .er.rc. This enables you to have the same metrics enabled in `er_print` and Performance Analyzer.

♦ ♦ ♦ CHAPTER 5

er_print Command-Line Performance Analysis Tool

This chapter explains how to use the `er_print` utility for performance analysis. For additional information, see `er_print`(1).

This chapter covers the following topics.

About `er_print`

The `er_print` utility prints a text version of the various data views supported by Performance Analyzer. The information is written to standard output unless you redirect it to a file. You must give the `er_print` utility the name of one or more experiments or experiment groups generated by the Collector as arguments.

The `er_print` utility only works on experiments that were recorded with Oracle Solaris Studio 12.3 and 12.4, and Oracle Developer Studio 12.5 and 12.6. An error is reported if you use an experiment recorded with any other version. If you have older experiments, you must use the version of `er_print` from the release with which the experiment was recorded.

You can use the `er_print` utility to display the performance metrics for functions, for callers and callees; the source code listing and disassembly listing; sampling information; dataspace data; thread analysis data, and execution statistics.

When invoked on more than one experiment or experiment groups, `er_print` aggregates the experiment data by default can also be used to compare the experiments. See "`compare { on | off | delta | ratio }`" on page 179 for more information.

For a description of the data collected by the Collector, see Chapter 2, "Performance Data".

For instructions on how to use Performance Analyzer to display information in a graphical format, see Chapter 4, "Performance Analyzer Tool" and the Performance Analyzer's Help menu.

`er_print` Syntax

The command-line syntax for the `er_print` utility is:

`er_print [ -script` *script* `|` *–command* `| - | -V ]` *experiment-list*

The options for the `er_print` utility are:

–

Read `er_print` commands entered from the keyboard.

`-script` *script*

Read commands from the file *script*, which contains a list of `er_print` commands, one per line. If the `-script` option is not present, `er_print` reads commands from the terminal or from the command line.

-*command* [*argument*]

Process the given command.

`-V`

Display version information and exit.

Multiple options that appear on the `er_print` command line are processed in the order they appear. You can mix scripts, hyphens, and explicit commands in any order. The default action if you do not supply any commands or scripts is to enter interactive mode, in which commands are entered from the keyboard. To exit interactive mode, type `quit` or Ctrl-D.

After each command is processed, any error messages or warning messages arising from the processing are printed. You can print summary statistics on the processing with the `procstats` command.

The commands accepted by the `er_print` utility are listed in the following sections.

You can abbreviate any command with a shorter string as long as the command is unambiguous. You can split a command into multiple lines by terminating a line with a backslash, \. Any line that ends in \ will have the \ character removed, and the content of the next line appended before the line is parsed. There is no limit, other than available memory, on the number of lines you can use for a command.

You must enclose arguments that contain embedded blanks in double quotes. You can split the text inside the quotes across lines.

If invoked with no arguments, `er_print` will print a help message.

Metric Lists

Many of the `er_print` commands use a list of metric keywords. The syntax of the list is:

metric-keyword-1`[:`*metric-keyword2…*`]`

For dynamic metrics, those based on measured data, a metric keyword consists of three parts: a metric flavor string, a metric visibility string, and a metric name string. These are joined with no spaces, as follows.

flavorvisibilityname

For static metrics, those based on the static properties of the load objects in the experiment (name, address, and size), a metric keyword consists of a metric name, optionally preceded by a metric visibility string, joined with no spaces:

`[`*visibility*`]`*name*

The metric *flavor* and metric *visibility* strings are composed of flavor and visibility characters.

The allowed metric flavor characters are listed in Table 8, "Metric Flavor Characters," on page 150. A metric keyword that contains more than one flavor character is expanded into a list of metric keywords. For example, `ie.user` is expanded into `i.user:e.user`. For more information on static metrics, see "Static Metric Information" on page 43.

TABLE 8 Metric Flavor Characters

Character	Description
`e`	Show exclusive metric value
`i`	Show inclusive metric value

The allowed metric visibility characters are listed in Table 9, "Metric Visibility Characters," on page 150. The order of the visibility characters in the visibility string does not affect the order in which the corresponding metrics are displayed. For example, both `i%.user` and `i.%user` are interpreted as `i.user:i%user`.

Metrics that differ only in the visibility are always displayed together in the standard order. If two metric keywords that differ only in the visibility are separated by some other keywords, the metrics appear in the standard order at the position of the first of the two metrics.

TABLE 9 Metric Visibility Characters

Character	Description
`.`	Show metric as a time. Applies to timing metrics and hardware counter metrics that measure cycle counts. Interpreted as "+" for other metrics.
`%`	Show metric as a percentage of the total program metric. For attributed metrics in the callers-callees list, show metric as a percentage of the inclusive metric for the selected function.
`+`	Show metric as an absolute value. For hardware counters, this value is the event count. Interpreted as a "`.`" for timing metrics.
`!`	Do not show any metric value. Cannot be used in combination with other visibility characters.

When both flavor and visibility strings have more than one character, the flavor is expanded first. Thus, `ie.%user` is expanded to `i.%user:e.%user`, which is then interpreted as `i.user:i%user:e.user:e%user`.

For static metrics, the visibility characters period (`.`), plus (`+`), and percent sign (`%`), are equivalent for the purposes of defining the sort order. Thus, `sort i%user`, `sort i.user`, and `sort i+user` all mean that Performance Analyzer should sort by inclusive user CPU time if it is visible in any form. `sort i!user` means Performance Analyzer should sort by inclusive user CPU time, regardless of whether it is visible.

You can use the visibility character exclamation point (`!`) to override the built-in visibility defaults for each flavor of metric.

If the same metric appears multiple times in the metric list, only the first appearance is processed and subsequent appearances are ignored. If the named metric is not on the list, it is appended to the list.

Table 10, "Metric Name Strings," on page 151 lists the available `er_print` metric name strings for timing metrics, synchronization delay metrics, memory allocation metrics, MPI tracing metrics, and the two common hardware counter metrics. For other hardware counter metrics, the metric name string is the same as the counter name. You can display a list of all the available metric name strings for the loaded experiments with the `metric_list` command. To list the counter names, issue the `collect -h` command with no additional arguments. See "Hardware Counter Profiling Data" on page 28 for more information on hardware counters.

TABLE 10 Metric Name Strings

Category	String	Description
Clock profiling metrics	`total`	Total Thread Time
	`totalcpu`	Total CPU Time
	`user`	User CPU Time
	`system`	System CPU Time
	`trap`	Trap CPU Time
	`lock`	User Lock Time
	`datapfault`	Data-Page Fault Time
	`textpfault`	Text-Page Fault Time
	`kernelpfault`	Kernel Page Fault Time
	`stop`	Stopped Time
	`wait`	CPU wait time
	`sleep`	Sleep Time
Hardware counter metrics	`insts`	Instructions issued Available on all supported systems.
	`cycles`	CPU cycles

Category	String	Description
		Available on most supported systems. In addition, each processor has its own set of counters. Use `collect -h` to see the full list of counters for your system.
	`CPI`	Cycles per instruction, calculated from `cycles` and `insts` metrics. Available only if both counters are recorded.
	`IPC`	Instructions per cycle, calculated from `cycles` and `insts` metrics. Available only if both counters are recorded.
OpenMP profiling metrics	`ompwork`	Time spent doing work either serially or in parallel
	`ompwait`	Time spent when OpenMP runtime is waiting for synchronization
	`masterthread`	Master Thread Time is the total time spent in the master thread. It is only available from Oracle Solaris experiments. It corresponds to wall-clock time.
Synchronization delay metrics	`sync`	Synchronization wait time
	`syncn`	Synchronization wait count
Heap tracing metrics	`heapalloccnt`	Number of allocations
	`heapallocbytes`	Bytes allocated
	`heapleakcnt`	Number of leaks
	`heapleakbytes`	Bytes leaked
I/O tracing metrics	`ioreadbytes`	Bytes Read
	`ioreadcnt`	Read Count
	`ioreadtime`	Read Time
	`iowritebytes`	Bytes Written
	`iowritecnt`	Write Count
	`iowritetime`	Write Time
	`ioothrcnt`	Other IO Count
	`ioothertime`	Other IO Time
	`ioerrornt`	IO Error Count
	`ioerrortime`	IO Error Time
Thread Analyzer metrics	`raccesses`	Data race accesses
	`deadlocks`	Deadlocks
MPI tracing metrics	`mpitime`	Time spent in MPI calls
	`mpisend`	Number of MPI point-to-point sends started
	`mpibytessent`	Number of bytes in MPI Sends
	`mpireceive`	Number of MPI point‐to‐point receives completed
	`mpibytesrecv`	Number of bytes in MPI Receives
	`mpiother`	Number of calls to other MPI functions

Category	String	Description
MPI profiling metrics	`mpiwork`	Time spent inside the MPI runtime doing work, such as processing requests or messages
	`mpiwait`	Time spent inside the MPI runtime but waiting for an event, buffer, or message
Static metrics	`name`	Keyword of output's name column
	`size`	Keyword to select the size metric
	`address`	Keyword to select the address metric

In addition to the name strings listed in Table 10, "Metric Name Strings," on page 151, two name strings can be used only in default metrics lists. These are `hwc`, which matches any hardware counter name, and `any`, which matches any metric name string. Also note that `cycles` and `insts` are common to SPARC® platforms and x86 platforms, but other flavors also exist that are architecture-specific.

To see the metrics available from the experiments you have loaded, issue the `metric_list` command.

Commands That Control the Function List

The following commands control how the function information is displayed.

`functions`

Write the function list with the currently selected metrics. The function list includes all functions in load objects that are selected for display of functions, and any load objects whose functions are hidden with the `object_select` command.

The default metrics printed are exclusive and inclusive user CPU time, in both seconds and percentage of total program metric. You can change the current metrics displayed with the `metrics` command, which you must issue before you issue the `functions` command. You can also change the defaults with the `dmetrics` command in an `.er.rc` file.

You can limit the number of lines written by using the `limit` command (see "Commands That Control Output" on page 178).

For applications written in the Java programming language, the displayed function information varies depending on whether the View mode is set to user, expert, or machine.

- User mode shows each method by name, with data for interpreted and HotSpot-compiled methods aggregated together. It also suppresses data for non-user-Java threads.
- Expert mode separates HotSpot-compiled methods from interpreted methods. It does not suppress non-user Java threads.
- Machine mode shows data for interpreted Java methods against the Java Virtual Machine (JVM) software as it does the interpreting, while data for methods compiled with the Java HotSpot virtual machine is reported for named methods. All threads are shown.

In all three modes, data is reported in the usual way for any C, C++, or Fortran code called by a Java target.

`metrics` *metric-spec*

Specify a selection of function-list metrics. The string *metric-spec* can either be the keyword `default`, which restores the default metric selection, or a list of metric keywords, separated by colons. The following example illustrates a metric list.

```
% metrics i.user:i%user:e.user:e%user
```

This command instructs the `er_print` utility to display the following metrics:

- Inclusive user CPU time in seconds
- Inclusive user CPU time percentage
- Exclusive user CPU time in seconds
- Exclusive user CPU time percentage

By default, the metric setting used is based on the `dmetrics` command processed from `.er.rc` files, as described in "Setting Defaults in `.er.rc` Files" on page 182. If a `metrics` command explicitly sets *metric-spec* to `default`, the default settings are restored as appropriate to the data recorded.

When metrics are reset, the default sort metric is set in the new list.

If *metric-spec* is omitted, the current metrics setting is displayed.

In addition to setting the metrics for the function list, the `metrics` command sets metrics for callers-callees, for data-derived output, and for index objects. The callers-callees metrics show the attributed metrics that correspond to those metrics in the functions list whose inclusive or exclusive metrics are shown, as well as the static metrics.

The dataspace metrics show the dataspace metrics for which data is available and that correspond to those metrics in the function list whose inclusive or exclusive metrics are shown, as well as the static metrics.

The index objects metrics show the index-object metrics corresponding to those metrics in the function list whose inclusive or exclusive metrics are shown, as well as the static metrics.

When the `metrics` command is processed, a message is printed showing the current metric selection. For the preceding example, the message is as follows.

```
current: i.user:i%user:e.user:e%user:name
```

For information about the syntax of metric lists, see "Metric Lists" on page 149. To see a listing of the available metrics, use the `metric_list` command.

If a `metrics` command has an error, it is ignored with a warning, and the previous settings remain in effect.

`sort` *metric_spec*

Sort the function list on *metric-spec*. The *visibility* in the metric name does not affect the sort order. If more than one metric is named in the *metric-spec*, use the first one that is visible. If none of the metrics named are visible, ignore the command. You can precede the *metric-spec* with a minus sign (-) to specify a reverse sort.

By default, the metric sort setting is based on the `dsort` command processed from `.er.rc` files, as described in "Setting Defaults in `.er.rc` Files" on page 182. If a `sort` command explicitly sets *metric_spec* to `default`, the default settings are used.

The string *metric-spec* is one of the metric keywords described in "Metric Lists" on page 149, as shown in this example.

```
sort i.user
```

This command tells the `er_print` utility to sort the function list by inclusive user CPU time. If the metric is not in the experiments that have been loaded, a warning is printed and the command is ignored. When the command is finished, the sort metric is printed.

`fsummary`

Write a summary panel for each function in the function list. You can limit the number of panels written by using the `limit` command (see "Commands That Control Output" on page 178).

The summary metrics panel includes the name, address, and size of the function or load object. For functions, it includes the name of the source file, object file, and load object. The panel displays all the recorded metrics for the selected function or load object, both exclusive and inclusive, as values and percentages. For more information about metrics, see "Function-Level Metrics: Exclusive, Inclusive, Attributed, and Static" on page 39.

`fsingle` *function-name* `[`*N*`]`

Write a summary panel for the specified function. The optional parameter *N* is needed for those cases where several functions have the same name. The summary metrics panel is written for the *N*th function with the given function name. When the command is given on the command line, *N* is required; if it is not needed, it is ignored. When the command is given interactively without *N* but *N* is required, a list of functions with the corresponding *N* value is printed.

For a description of the summary metrics for a function, see the `fsummary` command description.

Commands That Control the Callers-Callees List

The following commands control how the caller and callee information is displayed.

`callers-callees`

Print the callers-callees panel for each of the functions, in the order specified by the function sort metric (`sort`).

Within each caller-callee report, the callers and callees are sorted by the caller-callee sort metrics (`csort`). You can limit the number of panels written by using the `limit` command (see "Commands That Control Output" on page 178). The selected (center) function is marked with an asterisk, as shown in the following example.

```
Attr.       Name
User CPU
 sec.
4.440          commandline
0.            *gpf
```

```
4.080         gpf_b
0.360         gpf_a
```

In this example, `gpf` is the selected function; it is called by `commandline`, and it calls `gpf_a` and `gpf_b`.

Caller-callees can slow data for a stack fragment, not just a single function. Fragments can be controlled with the `cprepend`, `cappend`, `crmfirst`, and `crmlast` commands.

`csingle` *function-name* `[`*N*`]`

Write the callers-callees panel for the named function. The optional parameter *N* is needed for those cases where several functions have the same name. The callers-callees panel is written for the *N*th function with the given function name. When the command is given on the command line, *N* is required; if it is not needed, it is ignored. When the command is given interactively without *N* but *N* is required, a list of functions with the corresponding *N* value is printed.

`cprepend` *function-name [N | ADDR]*

When building a call stack, prepend the named function to the current call stack fragment. The optional parameter is needed where the function name is ambiguous; see "`source|src {` *filename* `|` *function-name* `} [` *N*`]" on page 160 for more information about specifying the parameter.

`cappend` *function-name [N | ADDR]*

When building a call stack, append the named function to the current call stack fragment. The optional parameter is needed where the function name is ambiguous; see "`source|src {` *filename* `|` *function-name* `} [` *N*`]" on page 160 for more information about specifying the parameter.

`crmfirst`

When building a call stack, remove the top frame from the call stack segment.

`crmlast`

When building a call stack, remove the bottom frame from the call stack segment.

Commands That Control the Call Tree List

This section describes the commands for the call tree.

`calltree`

Display the dynamic call graph from the experiment, showing the hierarchical metrics at each level.

Commands Common to Tracing Data

This section describes commands that you can use with experiments that contain tracing data.

`datasize`

Write the distribution of the size of the data referred to in tracing data in a logarithmic scale. For Heap Tracing, the size is the allocation or leak size. For I/O Tracing, the size if the number of Bytes transferred.

`duration`

Write the distribution of the duration of the events in tracing data in a logarithmic scale. For Synchronization Tracing, the duration is the Synchronization Delay. For I/O Tracing, the duration is the time spent in the I/O operation.

Commands That Control the Leak and Allocation Lists

This section describes the commands that relate to memory allocations and deallocations.

`leaks`

Display a list of memory leaks, aggregated by common call stack. Each entry presents the total number of leaks and the total bytes leaked for the given call stack. The list is sorted by the number of bytes leaked.

`allocs`

Display a list of memory allocations, aggregated by common call stack. Each entry presents the number of allocations and the total bytes allocated for the given call stack. The list is sorted by the number of bytes allocated.

`heap`

Write the list of allocations and leaks, aggregated by common callstack.

`heapstat`

Write the overall statistics of heap usage, including the peak memory usage for the application.

Commands That Control the I/O Activity Report

This section describes the commands that relate to I/O activity.

`ioactivity`

Write the report of all I/O activity, sorted by file.

`iodetail`

Write the report of all I/O activity, sorted by virtual file descriptor. A different virtual file descriptor is generated for each open of a file, even if the same file descriptor is returned from the open.

`iocallstack`

Write the report of all I/O activity, sorted by callstack, and aggregated over all events with the same callstack. For each aggregated callstack, include the callstack trace.

`iostat`

Write summary statistics for all I/O activity.

Commands That Control the Source and Disassembly Listings

The following commands control how annotated source and disassembly code is displayed.

source|src { *filename* **|** *function-name* **} [** *N* **]**

Write out annotated source code for either the specified file or the file containing the specified function. The file in either case must be in a directory in your path. If the source was compiled with the GNU Fortran compiler, you must add two underscore characters after the function name as it appears in the source.

Use the optional parameter *N* (a positive integer) only in those cases where the file or function name is ambiguous; in this case, the *N*th possible choice is used. If you provide an ambiguous name without the numeric specifier, the `er_print` utility prints a list of possible object-file names. If the name you gave was a function, the name of the function is appended to the object-file name, and the number that represents the value of *N* for that object file is also printed.

The function name can also be specified as *function”file”* , where *file* is used to specify an alternate source context for the function. Immediately following the first instruction, an index line is added for the function. Index lines are displayed as text within angle brackets in the following form:

```
<Function: f_name>
```

The default source context for any function is defined as the source file to which the first instruction in that function is attributed. It is normally the source file compiled to produce the object module containing the function. Alternate source contexts consist of other files that contain instructions attributed to the function. Such contexts include instructions coming from include files and instructions from functions inlined into the named function. If there are any alternate source contexts, include a list of extended index lines at the beginning of the default source context to indicate where the alternate source contexts are located in the following form:

```
<Function: f, instructions from source file src.h>
```

Note - If you use the `-source` argument when invoking the `er_print` utility on the command line, the backslash escape character must prepend the file quotes. In other words, the function name is of the form `function\"file\"`. The backslash is not required, and should not be used, when the `er_print` utility is in interactive mode.

Normally, when the default source context is used, metrics are shown for all functions from that file. Referring to the file explicitly shows metrics only for the named function.

`disasm|dis {` *filename* `|` *function-name* `} [` *N*`]`

Write out annotated disassembly code for either the specified file, or the file containing the specified function. The file must be in a directory in your path.

The optional parameter *N* is used in the same way as for the `source` command.

`scc` *com-spec*

Specify the classes of compiler commentary that are shown in the annotated source listing. The class list is a colon-separated list of classes containing zero or more of the following message classes.

TABLE 11 Compiler Commentary Message Classes

Class	Meaning
`b[asic]`	Show the basic level messages.

Class	Meaning
`v[ersion]`	Show version messages, including source file name and last modified date, versions of the compiler components, compilation date and options.
`pa[rallel]`	Show messages about parallelization.
`q[uery]`	Show questions about the code that affect its optimization.
`l[oop]`	Show messages about loop optimizations and transformations.
`pi[pe]`	Show messages about pipelining of loops.
`i[nline]`	Show messages about inlining of functions.
`m[emops]`	Show messages about memory operations, such as load, store, and prefetch.
`f[e]`	Show front-end messages.
`co[degen]`	Show code generator messages.
`cf`	Show compiler flags at the bottom of the source.
`all`	Show all messages.
`none`	Do not show any messages.

The classes `all` and `none` cannot be used with other classes.

If no `scc` command is given, the default class shown is `basic`. If the `scc` command is given with an empty *class-list*, compiler commentary is turned off. The `scc` command is normally used only in an `.er.rc` file.

`sthresh` *value*

Specify the threshold percentage for highlighting metrics in the annotated source code. If the value of any metric is equal to or greater than *value* % of the maximum value of that metric for any source line in the file, the line on which the metrics occur has `##` inserted at the beginning of the line.

`dcc` *com-spec*

Specify the classes of compiler commentary that are shown in the annotated disassembly listing. The class list is a colon-separated list of classes. The list of available classes is the same as the list of classes for annotated source code listing shown in Table 11, "Compiler Commentary Message Classes," on page 161. You can add the options in the following table to the class list.

TABLE 12 Additional Options for the `dcc` Command

Option	Meaning
`h[ex]`	Show the hexadecimal value of the instructions.
`noh[ex]`	Do not show the hexadecimal value of the instructions.
`s[rc]`	Interleave the source listing in the annotated disassembly listing.
`nos[rc]`	Do not interleave the source listing in the annotated disassembly listing.
`as[rc]`	Interleave the annotated source code in the annotated disassembly listing.

`dthresh` *value*

Specify the threshold percentage for highlighting metrics in the annotated disassembly code. If the value of any metric is equal to or greater than *value* % of the maximum value of that metric for any instruction line in the file, the line on which the metrics occur has `##` inserted at the beginning of the line.

`cc` *com-spec*

Specify the classes of compiler commentary that are shown in the annotated source and disassembly listing. The class list is a colon-separated list of classes. The list of available classes is the same as the list of classes for annotated source code listing shown in Table 11, "Compiler Commentary Message Classes," on page 161.

Commands That Control PCs and Lines

The following commands control how the program counters and lines information is displayed.

`pcs`

Write a list of program counters (PCs) and their metrics, ordered by the current sort metric. The list includes lines that show aggregated metrics for each load object whose functions are hidden with the `object_select` command.

`psummary`

Write the summary metrics panel for each PC in the PC list, in the order specified by the current sort metric.

`lines`

Write a list of source lines and their metrics, ordered by the current sort metric. The list includes lines that show aggregated metrics for each function that does not have line-number information, or whose source file is unknown, and lines that show aggregated metrics for each load object whose functions are hidden with the `object_select` command.

`lsummary`

Write the summary metrics panel for each line in the lines list, in the order specified by the current sort metric.

Commands That Control Searching For Source Files

The `er_print` utility looks for the source files and load object files referenced in an experiment. You can use the directives described in this section to help `er_print` find the files referenced by your experiment.

See "How the Tools Find Source Code" on page 231 for a description of the process used to find an experiment's source code, including how these directives are used.

`setpath` *path-list*

Set the path used to find source and object files. *path-list* is a colon-separated list of directories, jar files, or zip files.. If any directory has a colon character in it, escape it with a backslash. The special directory name, `$expts`, refers to the set of current experiments in the order in which they were loaded. You can abbreviate it with a single `$` character.

The default path is: `$expts:..` which is the directories of the loaded experiments and the current working directory.

Use `setpath` with no argument to display the current path.

`setpath` commands must not be used in `.er.rc` files.

`addpath` *path-list*

Append *path-list* to the current `setpath` settings.

`addpath` commands can be used in `.er.rc` files, and will be concatenated.

`pathmap` *old-prefix new-prefix*

If a file cannot be found using the *path-list* set by `addpath` or `setpath`, you can specify one or more path remappings with the `pathmap` command. In any path name for a source file, object file, or shared object that begins with the prefix specified with *old-prefix*, the old prefix is replaced by the prefix specified with *new-prefix*. The resulting path is then used to find the file. Multiple `pathmap` commands can be supplied, and each is tried until the file is found.

Commands That Control the Dataspace List

Data Space commands are applicable only to hardware counter experiments where memoryspace/dataspace data was recorded, either by default or explicitly for precise counters on either Oracle Solaris x86 or SPARC systems. See the `collect(1)` man page for more information.

Dataspace data is only available for profile hits that occurred in functions that were compiled with the `-xhwcprof` flag. The `-xhwcprof` flag is applicable to compiling with the C, C++ and Fortran compilers and is only meaningful on SPARC platforms; it is ignored on other platforms.

See “Hardware Counter Profiling Data” on page 28 for more information about these types of data. See “Hardware Counter Profiling with `collect -h`” on page 69 for information about the command used to perform hardware counter overflow profiling.

For information about the `-xhwcprof` compiler option, see *Oracle Developer Studio 12.6: Fortran User's Guide*, *Oracle Developer Studio 12.6: C User's Guide*, or *Oracle Developer Studio 12.6: C++ User's Guide*.

`data_objects`

Write the list of data objects with their metrics.

`data_single` *name* `[`*N*`]`

Write the summary metrics panel for the named data object. The optional parameter N is needed for those cases where the object name is ambiguous. When the directive is on the command line, N is required; if it is not needed, it is ignored.

`data_layout`

Write the annotated data object layouts for all program data objects with data-derived metric data, sorted by the current data sort metric values for the structures as a whole. Show each aggregate data object with the total metrics attributed to it, followed by all of its elements in offset order, each with their own metrics and an indicator of its size and location relative to 32-byte blocks, where:

<	Element fits block entirely.
/	Element starts a block.
|	Element is inside a block.
\	Element completes a block.
#	Element size requires multiple blocks.
X	Element spans multiple blocks but could fit within one block.
?	Undefined.

Commands That Control Index Object Lists

Index objects commands are applicable to all experiments. An index object list is a list of objects for whom an index can be computed from the recorded data. Index objects are predefined for Threads, CPUs, Samples, and Seconds, among others. You can get the full list with the `indxobj_list` command. You can define other index objects with the `indxobj_define` command.

The following commands control the index-object lists.

`indxobj` *indxobj-type*

Write the list of the index objects that match the given type, along with their metrics. Metrics and sorting for index objects is the same as those for the function list, but containing exclusive metrics only. The name *indxobj-type* can also be used directly as the command.

`indxobj_list`

Write the list of known types of index objects, as used for *indxobj-type* in the `indxobj` command. Index objects are predefined for Threads, CPUs, Samples, and Seconds, among others.

`indxobj_define` *indxobj-type index-exp*

Define a new type of index object with a mapping of packets to the object given by the *index-exp*. The syntax of the expression is described in "Expression Grammar" on page 185.

The *indxobj-type* must not already be defined. Its name is case-insensitive, must be entirely composed of alphanumeric characters or the '_' character, and begin with an alphabetic character.

The *index-exp* must be syntactically correct, or an error is returned and the definition is ignored. If the *index-exp* contains any blanks, it must be surrounded by double quotes (").

The `<Unknown>` index object has an index of -1, and the expression used to define a new index object should support recognizing `<Unknown>`.

For example, for index objects based on virtual or physical PC, the expression should be of the following form:

```
VIRTPC>0?VIRTPC:-1
```

Commands That Control Memory Object Lists

Memory Object commands are applicable only to hardware counter experiments where memoryspace data was recorded, either by default or explicitly for precise counters on either Solaris x86 or SPARC systems.. See the `collect`(1) man page for more information.

Memory Objects are components in the memory subsystem, such as cache-lines, pages, memory-banks, *etc*. The object is determined from an index computed from the virtual and/or physical address as recorded. Memory objects are predefined for virtual and physical pages, for sizes of 8KB, 64KB, 512KB, and 4 MB. You can define others with the `memobj_define` command.

`memobj` *mobj-type*

Write the list of the memory objects of the given type with the current metrics. Metrics used and sorting as for the data space list. You can also use the name `mobj_type` directly as the command.

`mobj_list`

Write the list of known types of memory objects, as used for *mobj-type* in the `memobj` command.

`mobj_define` *mobj-type index-exp*

Define a new type of memory objects with a mapping of VA/PA to the object given by the *index-exp*. The syntax of the expression is described in "Expression Grammar" on page 185.

The *mobj-type* must not already be defined and it cannot match any existing command, or any Index Object type (see below). Its name must be entirely composed of alphanumeric characters or the '_' character, and begin with an alphabetic character.

The *index-exp* must be syntactically correct. If it is not syntactically correct, an error is returned and the definition is ignored.

The `<Unknown>` memory object has an index of -1, and the expression used to define a new memory object should support recognizing `<Unknown>`. For example, for VADDR-based objects, the expression should be of the following form:

`VADDR>255?`*expression* `:-1`

For PADDR-based objects, the expression should be of the following form:

`PADDR>0?`*expression*`:-1`

`memobj_drop` *mobj_type*

Drop the memory object of the given type.

`machinemodel` *model_name*

Create memory objects as defined in the specified machine model. The *model_name* is a file name, either in the user's current directory, or in the user's home directory, or it is the name of a machine model defined in the release. Machine model files are stored with a suffix of `.ermm`. If the *model_name* on the `machinemodel` command does not end with that suffix, the *model_name* with `.ermm` appended will be used. If the *model_name* begins with a `/`, it is assumed to be an absolute path, and only that path (with `.ermm` appended, if needed) will be tried. If the *model_name* contains a `/`, only that pathname relative to the current directory, or the user's home directory will be tried.

A machine model file can contain comments and `mobj_define` commands. Any other commands are ignored. A `machinemodel` command can appear in a `.er.rc` file. If a machine model had been loaded, either by the command or by reading an experiment with a machine model recorded in it, a subsequent `machinemodel` command will remove any definitions coming from the previous machine model.

If the *model_name* is missing, print a list of all known machine models. If the *model_name* is a zero-length string, unload any loaded machine model.

Commands for the OpenMP Index Objects

Use the following commands to print information for OpenMP index objects.

`OMP_preg`

Print a list of the OpenMP parallel regions executed in the experiment with their metrics. This command is available only for experiments with OpenMP 3.0 or 3.1 performance data.

`OMP_task`

Print a list of the OpenMP tasks executed in the experiment with their metrics. This command is available only for experiments with OpenMP 3.0 or 3.1 performance data.

Commands That Support Thread Analyzer

The following commands are in support of Thread Analyzer. See the *Oracle Developer Studio 12.6: Thread Analyzer User's Guide* for more information about the data captured and shown.

`races`

Writes a list of all data races in the experiments. Data-race reports are available only from experiments with data-race-detection data.

`rdetail` *race-id*

Writes the detailed information for the given *race-id*. If the *race-id* is set to `all`, detailed information for all data races is shown. Data race reports are available only from experiments with data race detection data.

`deadlocks`

Writes a list of all detected real and potential deadlocks in the experiments. Deadlock reports are available only from experiments with deadlock-detection data.

`ddetail` *deadlock-id*

Writes the detailed information for the given *deadlock-id*. If the *deadlock-id* is set to `all`, detailed information for all deadlocks is shown. Deadlock reports are available only from experiments with deadlock-detection data.

Commands That List Experiments, Samples, Threads, and LWPs

This section describes the commands that list experiments, samples, threads, and LWPs.

`experiment_list`

Display the full list of experiments loaded with their ID number. Each experiment is listed with an index, which is used when selecting samples, threads, or LWPs, and a PID, which can be used for advanced filtering.

The following example shows an experiment list.

```
(er_print) experiment_list
 ID Sel   PID Experiment
=== === ===== ================
  1 yes 13493 test.1.er
  2 yes 24994 test.2.er
  3 yes 25653 test.2.er/_f8.er
  4 yes 25021 test.2.er/_x5.er
```

`sample_list`

Display the list of samples currently selected for analysis.

The following example shows a sample list.

```
(er_print) sample_list
Exp Sel     Total
=== ======= =====
  1 1-6        31
  2 7-10,15    31
```

`lwp_list`

Display the list of LWPs currently selected for analysis.

`thread_list`

Display the list of threads currently selected for analysis.

`cpu_list`

Display the list of CPUs currently selected for analysis.

Commands That Control Filtering of Experiment Data

You can specify filtering of experiment data in two ways:

- By specifying a filter expression, which is evaluated for each data record to determine whether the record should be included
- By selecting experiments, samples, threads, CPUs, and LWPs for filtering

Specifying a Filter Expression

You can specify a filter expression with the `filters` command.

`filters` *filter-exp*

filter-exp is an expression that evaluates as true for any data record that should be included, and false for records that should not be included. The grammar of the expression is described in "Expression Grammar" on page 185.

Listing Keywords for a Filter Expression

You can see a list of operands or keywords that you can use in a filter expression on your experiment.

`describe`

Print the list of keywords that can be used to build a filter expression. Some keywords and the grammar of a filter expression is described in "Expression Grammar" on page 185.

Selecting Samples, Threads, LWPs, and CPUs for Filtering

The syntax of a selection is shown in the following example. This syntax is used in the command descriptions.

`[`*experiment-list*`:]`*selection-list*`[+[`
experiment-list`:]`*selection-list* `… ]`

Selection Lists

Each selection list can be preceded by an experiment list, separated from it by a colon and no spaces. To make multiple selections, join selection lists with a + sign.

The experiment list and the selection list have the same syntax, which is either the keyword `all` or a list of numbers or ranges of numbers (*n*-*m*) separated by commas but no spaces, as shown in the following example.

```
2,4,9-11,23-32,38,40
```

The experiment numbers can be determined by using the `experiment_list` command.

Some examples of selections are:

```
1:1-4+2:5,6
all:1,3-6
```

In the first example, objects 1 through 4 are selected from experiment 1 and objects 5 and 6 are selected from experiment 2. In the second example, objects 1 and 3 through 6 are selected from all experiments. The objects may be LWPs, threads, or samples.

Selection Commands

The commands to select LWPs, samples, CPUs, and threads are not independent. If the experiment list for a command is different from that for the previous command, the experiment list from the latest command is applied to all three selection targets, LWPs, samples, and threads, in the following way.

- Existing selections for experiments that are not in the latest experiment list are turned off.
- Existing selections for experiments in the latest experiment list are kept.
- Selections are set to `all` for targets for which no selection has been made.

`sample_select` *sample-spec*

Select the samples for which you want to display information. The list of samples you selected is displayed when the command finishes.

`lwp_select` *lwp-spec*

Select the LWPs about which you want to display information. The list of LWPs you selected is displayed when the command finishes.

`thread_select` *thread-spec*

Select the threads about which you want to display information. The list of threads you selected is displayed when the command finishes.

`cpu_select` *cpu-spec*

Select the CPUs about which you want to display information. The list of CPUs you selected is displayed when the command finishes.

Commands That Control Load Object Expansion and Collapse

These commands determine how load objects are displayed by the `er_print` utility.

`object_list`

Display a two-column list showing the status and names of all load objects. The show/hide/API status of each load object is shown in the first column, and the name of the object is shown in the second column. The name of each load object is preceded either by a `show` that indicates that the functions of that object are shown in the function list (expanded), by a `hide` that indicates that the functions of that object are not shown in the function list (collapsed), or by `API-only` if only those functions representing the entry point into the load object are shown. All functions for a collapsed load object map to a single entry in the function list representing the entire load object.

The following is an example of a load object list.

```
(er_print) object_list
Sel  Load Object
==== ==================
hide <Unknown>
show <Freeway>
show <libCstd_isa.so.1>
show <libnsl.so.1>
show <libmp.so.2>
show <libc.so.1>
show <libICE.so.6>
show <libSM.so.6>
show <libm.so.1>
show <libCstd.so.1>
show <libX11.so.4>
show <libXext.so.0>
show <libCrun.so.1>
show <libXt.so.4>
show <libXm.so.4>
show <libsocket.so.1>
show <libgen.so.1>
show <libcollector.so>
show <libc_psr.so.1>
show <ld.so.1>
show <liblayout.so.1>
```

`object_show` *object1,object2,...*

Set all named load objects to show all their functions. The names of the objects can be either full path names or the basename. If the name contains a comma character, the name must be surrounded by double quotation marks. If the string “all” is used to name the load object, functions are shown for all load objects.

`object_hide` *object1,object2,...*

Set all named load objects to hide all their functions. The names of the objects can be either full path names or the basename. If the name contains a comma character, the name must be surrounded by double quotation marks. If the string “all” is used to name the load object, functions are shown for all load objects.

`object_api` *object1,object2,...*

Set all named load objects to show all only the functions representing entry points into the library. The names of the objects can be either full path names or the basename. If the name contains a comma character, the name must be surrounded by double quotation marks. If the string “all” is used to name the load object, functions are shown for all load objects.

`objects_default`

Set all load objects according to the initial defaults from `.er.rc` file processing.

`object_select` *object1,object2,...*

Select the load objects for which you want to display information about the functions in the load object. Functions from all named load objects are shown; functions from all others are hidden. *object-list* is a list of load objects separated by commas but no spaces. If functions from a load object are shown, all functions that have non-zero metrics are shown in the function list. If functions from a load object are hidden, its functions are collapsed, and only a single line with metrics for the entire load object instead of its individual functions is displayed.

The names of the load objects should be either full path names or the basename. If an object name itself contains a comma, you must surround the name with double quotation marks.

Commands That List Metrics

The following commands list the currently selected metrics and all available metric keywords.

`metric_list`

Display the currently selected metrics in the function list and a list of metric keywords that you can use in other commands (for example, `metrics` and `sort`) to reference various types of metrics in the function list.

`cmetric_list`

Display the currently selected caller-callee attributed metrics and the metric currently used for sorting.

`data_metric_list`

Display the currently selected data-derived metrics and a list of metrics and keyword names for all data-derived reports. Display the list in the same way as the output for the `metric_list` command, but include only those metrics that have a data-derived flavor and static metrics.

`indx_metric_list`

Display the currently selected index-object metrics and a list of metrics and keyword names for all index object reports. Display the list in the same way as the `metric_list` command, but include only those metrics that have an exclusive flavor, and static metrics.

Commands That Control Output

The following commands control `er_print` display output.

`outfile {`*filename***`|-|--}`**

Close any open output file, then open *filename* for subsequent output. When opening *filename*, clear any pre-existing content. If you specify a dash (`-`) instead of *filename*, output is written to standard output. If you specify two dashes (`--`) instead of *filename*, output is written to standard error.

`appendfile` *filename*

Close any open output file and open *filename*, preserving any pre-existing content, so that subsequent output is appended to the end of the file. If *filename* does not exist, the functionality of the `appendfile` command is the same as for the `outfile` command.

`limit` *n*

Limit any output to the first *n* entries of the report, where *n* is an unsigned integer. If *n* is zero, remove any limit. If *n* is omitted, print the current limit.

`name { long | short } [ :{` *shared-object-name* **`|`** *no-shared-object-name* **`} ]`**

Specify whether to use the long or the short form of function names (C++ and Java only). If *shared-object-name* is specified, append the shared-object name to the function name.

`viewmode { user| expert | machine }`

Set the mode to one of the following:

`user`	For Java experiments, show the Java call stacks for Java threads, and do not show housekeeping threads. The function list includes a function `<JVM-System>` representing aggregated time from non-Java threads. When the JVM software does not report a Java call stack, time is reported against the function `<no Java callstack recorded>`. For OpenMP experiments, show reconstructed call stacks similar to those obtained when the program is compiled without OpenMP. Add special functions, with the names of form `<OMP-*>`, when the OpenMP runtime is performing certain operations.
`expert`	For Java experiments, show the Java call stacks for Java threads when the user's Java code is being executed, and machine call stacks when JVM code is being executed or when the JVM software does not report a Java call stack. Show the machine call stacks for housekeeping threads. For OpenMP experiments, show compiler-generated functions representing parallelized loops, tasks, and such, which are aggregated with user functions in user mode. Add special functions, with the names of form `<OMP-*>`, when the OpenMP runtime is performing certain operations. Functions from the OpenMP runtime code `libmtsk.so` are suppressed.
`machine`	For Java experiments and OpenMP experiments, show the actual native call stacks for all threads.

For all experiments other than Java experiments and OpenMP experiments, all three modes show the same data.

compare { on | off | delta | ratio }

Set comparison mode off (`compare off`, the default), or on (`compare on`), or delta (`compare delta`) or ratio (`compare ratio`). If comparison mode is off, when multiple experiments are read the data is aggregated. If comparison is enabled, when multiple experiments are loaded separate columns of metrics are shown for the data from each experiment. If comparison mode is delta, the base experiment shows absolute metrics but the comparison experiment shows differences between it and the base. If comparison mode is ratio, the comparison experiment shows ratios between it and the base.

Comparison mode will treat each experiment or experiment-group as a separate compare group. The first experiment or experiment-group argument is the base group. If you want to include more than one experiment in a compare group, you must create an experiment-group file to use as a single argument to `er_print`.

`printmode` *string*

Set the print mode from the *string*. If the *string* is `text`, printing will be done in tabular form. If the *string* is a single character, printing will be done as a delimiter-separated list, with the single character as the delimiter. If the *string* is `html`, printing will be formatted for an HTML table. Any other *string* is invalid, and the command will be ignored.

The `printmode` setting is used only for those commands that generate tables, such as `functions`, `memobj`, `indxobj`. The setting is ignored for other printing commands, including `source` and `disassembly`.

Commands That Print Other Information

The following `er_print` subcommands display miscellaneous information about the experiment.

`header` *exp-id*

Display descriptive information about the specified experiment. The *exp-id* can be obtained from the `exp_list` command. If the *exp-id* is `all` or is not given, the information is displayed for all experiments loaded.

Following each header, any errors or warnings are printed. Headers for each experiment are separated by a line of dashes.

If the experiment directory contains a file named `notes`, the contents of that file are prepended to the header information. A notes file may be manually added or edited or specified with `-C` "*comment*" arguments to the `collect` command.

exp-id is required on the command line, but not in a script or in interactive mode.

`ifreq`

Write a list of instruction frequency from the measured count data. The instruction frequency report can only be generated from count data.

`objects`

List the load objects with any error or warning messages that result from the use of the load object for performance analysis. The number of load objects listed can be limited by using the `limit` command (see "Commands That Control Output" on page 178).

`overview` *exp_id*

Write an overview of all data summed over all experiments. Function list metrics are indicated with [X] while hot metrics have asterisks highlighting their values.

`sample_detail` [*exp_id*]

Write the detailed sample information for the specified experiment. *exp_id* is the numeric identifier of the experiment as given by the `experiment_list` command. If *exp_id* is omitted, or is `all`, write the sum and the statistics for all samples in all experiments.

The report now generated by `sample_detail` was printed with the `overview` command in previous releases.

`statistics` *exp_id*

Write out execution statistics, aggregated over the current sample set for the specified experiment. For information on the definitions and meanings of the execution statistics that are presented, see the `getrusage`(3C) and `proc`(4) man pages. The execution statistics include statistics from system threads for which the Collector does not collect any data.

The *exp_id* can be obtained from the `experiment_list` command. If the *exp_id* is not given, the sum of data for all experiments is displayed, aggregated over the sample set for each experiment. If *exp_id* is `all`, the sum and the individual statistics for each experiment are displayed.

Commands for Experiments

These commands are for use in scripts and interactive mode only. They are not allowed on the command line.

`add_exp` *exp_name*

Add the named experiment or experiment group to the current session.

`drop_exp` *exp_name*

Drop the named experiment from the current session.

`open_exp` *exp_name*

Drop all loaded experiments from the session, and then load the named experiment or experiment group.

Setting Defaults in `.er.rc` Files

The `er_print` utility reads settings in resource files named `.er.rc` from several locations to determine default values. The files are read in the following order:

1. System resource file /*Studio-installation-dir*/`lib/analyzer/lib/er.rc`
2. User's `.er.rc` resource file if it exists in the user's home directory.
3. A `.er.rc` resource file if it exists in the current directory from which you executed the `er_print` command.

The settings of each file override the settings of the files read before it. Defaults from the `.er.rc` file in your home directory override the system defaults, and defaults from the `.er.rc` file in the current directory override both home and system defaults.

Any settings in `.er.rc` that apply to source and disassembly compiler commentary are also used by the `er_src` utility.

You can use the following commands in your `.er.rc` file to set the defaults for `er_print` and `er_src`. You can use these commands only for setting defaults, not as input for the `er_print` utility.

You can include a `.er.rc` defaults file in your home directory to set defaults for all experiments, or in any other directory to set defaults locally. When the `er_print` utility, the `er_src` utility, or the Performance Analyzer is started, the current directory and your home directory are scanned for `.er.rc` files. These files are read if they are present, and the system defaults file is also read. Defaults from the `.er.rc` file in your home directory override the system defaults, and defaults from the `.er.rc` file in the current directory override both home and system defaults.

Note - To ensure that you read the defaults file from the directory where your experiment is stored, you must start the `er_print` utility from that directory.

These files can contain `scc`, `sthresh`, `dcc`, `dthresh`, `addpath`, `pathmap`, `name`, `mobj_define`, `indxobj_define`, `object_show`, `object_hide`, `object_api`, `compare`, `printmode`, `machinemodel`, and `viewmode` commands, as described previously in this chapter. They can also contain the following commands, which cannot be used on either the command line or in scripts:

`dmetrics` *metric-spec*

Specify the default metrics to be displayed or printed in the function list. The syntax and use of the metric list is described in the section "Metric Lists" on page 149. The order of the metric keywords in the list determines the order in which the metrics are presented.

Default metrics for the Callers-Callees list are derived from the function list default metrics by adding the corresponding attributed metric before the first occurrence of each metric name in the list.

`dsort` *metric-spec*

Specify the default metric by which the function list is sorted. The sort metric is the first metric in this list that matches a metric in any loaded experiment, subject to the following conditions:

- If the entry in *metric-spec* has a visibility string of an exclamation point, !, the first metric whose name matches is used, regardless of whether it is visible.

- If the entry in *metric-spec* has any other visibility string, the first visible metric whose name matches is used.

The syntax and use of the metric list is described in the section "Metric Lists" on page 149.

The default sort metric for the Callers-Callees list is the attributed metric corresponding to the default sort metric for the function list.

`en_desc { on | off | =`*regexp*`}`

Set the mode for reading descendant experiments to `on` (enable all descendants) or `off` (disable all descendants). If the =*regexp* is used, enable data from those experiments whose executable name matches the regular expression. The default setting is `on` to follow all descendants.

In reading experiments with descendants, any sub-experiments that contain little or no performance data are ignored by Performance Analyzer and `er_print`.

Miscellaneous Commands

The following commands perform miscellaneous tasks in the `er_print` utility.

`procstats`

Print the accumulated statistics from processing data.

`script` *filename*

Process additional commands from the script file *filename*.

`version`

Print the current release number of the `er_print` utility.

`quit`

Terminate processing of the current script, or exit interactive mode.

`exit`

An alias for `quit`.

`help`

Print a list of `er_print` commands.

`# ...`

Comment line; used in scripts or a `.er.rc` file.

Expression Grammar

A common grammar is used for an expression defining a filter and an expression used to compute a memory object index.

The grammar specifies an expression as a combination of operators and operands or keywords. For filters, if the expression evaluates to true, the packet is included; if the expression evaluates to false, the packet is excluded. For memory objects or index objects, the expression is evaluated to an index that defines the particular memory object or index object referenced in the packet.

Operands in an expression can be labels, constants, or fields within a data record, as listed with the `describe` command. The operands include `THRID`, `LWPID`, `CPUID` , `USTACK`, `XSTACK`, `MSTACK`, `LEAF`, `VIRTPC`, `PHYSPC`, `VADDR`, `PADDR`, `DOBJ`, `TSTAMP`, `SAMPLE`, `EXPID`, `PID`, or the name of a memory object. Operand names are case-insensitive.

`USTACK`, `XSTACK`, and `MSTACK` represent the function call stacks in user view, expert view, and machine view, respectively.

`VIRTPC`, `PHYSPC`, `VADDR`, and `PADDR` are non-zero only when "+" is specified for Hardware-counter-profiling or clock-profiling. Furthermore, `VADDR` is less than 256 when the real virtual address could not be determined. `PADDR` is zero if `VADDR` could not be determined, or if the virtual address could not be mapped to a physical address. Likewise, `VIRTPC` is zero if backtracking failed or was not requested, and `PHYSPC` is zero if either `VIRTPC` is zero, or the `VIRTPC` could not be mapped to a physical address.

Operators include the usual logical operators and arithmetic (including shift) operators, in C notation, with C precedence rules, and an operator for determining whether an element is in a set (`IN`) or whether any or all of a set of elements is contained in a set (`SOME IN` or `IN`, respectively). An additional operator `ORDERED IN` determines whether all elements from the left operand appear in the same sequence in the right operand. Note that the `IN` operator requires all elements from the left operand to appear in the right operand but does not enforce the order.

If-then-else constructs are specified as in C, with the `?` and `:` operators. Use parentheses to ensure proper parsing of all expressions. On the `er_print` command lines, the expression cannot be split across lines. In scripts or on the command line, the expression must be inside double quotes if it contains blanks.

Filter expressions evaluate to a Boolean value, true if the packet should be included, and false if it should not be included. Thread, CPU, experiment-id, process-pid, and sample filtering are based on a relational expression between the appropriate keyword and an integer, or using the `IN` operator and a comma-separated list of integers.

Time-filtering is used by specifying one or more relational expressions between `TSTAMP` and a time, given in integer nanoseconds from the start of the experiment whose packets are being processed. Times for samples can be obtained using the `overview` command. Times in the `overview` command are given in seconds, and must be converted to nanoseconds for time-filtering. Times can also be obtained from the Timeline display in Performance Analyzer.

Function filtering can be based either on the leaf function, or on any function in the stack. Filtering by leaf function is specified by a relational expression between the `LEAF` keyword and an integer function ID, or using the `IN` operator and the construct `FNAME("`*regexp*`")`, where *regexp* is a regular expression as specified on the `regexp`(5) man page. The entire name of the function, as given by the current setting of *name*, must match.

Filtering based on any function in the call stack is specified by determining if any function in the construct `FNAME("`*regexp*`")` is in the array of functions represented by the keyword `USTACK` using the expression `(FNAME("myfunc") SOME IN USTACK)`. `FNAME` can also be used to filter the machine view of the stack (`MSTACK`) and the expert view (`XSTACK`) in the same way.

Data object filtering is analogous to stack function filtering, using the `DOBJ` keyword and the construct `DNAME("`*regexp*`")` enclosed in parentheses.

Memory object filtering is specified using the name of the memory object, as shown in the `mobj_list` command, and the integer index of the object, or the indices of a set of objects. (The `<Unknown>` memory object has index -1.)

Index object filtering is specified using the name of the index object, as shown in the `indxobj_list` command, and the integer index of the object, or the indices of a set of objects. (The `<Unknown>` index object has index -1.)

Data object filtering and memory object filtering are meaningful only for hardware counter packets with dataspace data; all other packets are excluded under such filtering.

Direct filtering of virtual addresses or physical addresses is specified with a relational expression between `VADDR` or `PADDR`, and the address.

Memory object definitions (see “`mobj_define` *mobj-type index-exp*” on page 168) use an expression that evaluates to an integer index, using either the `VADDR` keyword or `PADDR` keyword. The definitions are applicable only to hardware counter packets for memory counters and dataspace data. The expression should return an integer, or -1 for the `<Unknown>` memory object.

Index object definitions (see “`indxobj_define` *indxobj-type index-exp*” on page 167) use an expression that evaluates to an integer index. The expression should return an integer, or -1 for the `<Unknown>` index object.

Example Filter Expressions

This section shows examples of filter expressions that can be used with the `er_print -filters` command, and in the Advanced Customer Filters dialog box.

With the `er_print -filters` command, the filter expression is enclosed in single quotes, similar to the following example:

```
er_print -filters 'FNAME("myfunc") SOME IN USTACK' -functions test.1.er
```

EXAMPLE 5 Filter Functions by Name and Stack

To filter functions named `myfunc` from the user function stack:

```
FNAME("myfunc") SOME IN USTACK
```

EXAMPLE 6 Filter Events by Thread and CPU

To see events from thread 1 when it was running on CPU 2 only:

```
THRID == 1 && CPUID == 2
```

EXAMPLE 7 Filter Events by Index Object

If an index object, `THRCPU`, is defined as "`CPUID<<16|THRID`", the following filter is equivalent to the filter to see events from thread 1 when running on CPU 2:

```
THRCPU == 0x10002
```

EXAMPLE 8 Filter Events Occurring in a Specified Time Period

To filter events from experiment 2 that occurred during the period between second 5 and second 9:

```
EXPID==2 && TSTAMP >= 5000000000 && TSTAMP < 9000000000
```

EXAMPLE 9 Filter Events From a Particular Java Class

To filter events that have any method from a particular Java class in the stack (in user view mode):

```
FNAME("myClass.*") SOME IN USTACK
```

EXAMPLE 10 Filter Events by Internal Function ID and Call Sequence

If function IDs are known (as shown in Performance Analyzer), to filter events that contain a particular call sequence in the machine call stack:

```
(314,272) ORDERED IN MSTACK
```

EXAMPLE 11 Filter Events by State or Duration

If the `describe` command lists the following properties for a clock profiling experiment:

```
MSTATE    UINT32  Thread state
NTICK     UINT32  Duration
```

you can select events that are in a particular state using the following filter:

```
MSTATE == 1
```

Alternatively, you can use the following filter to select events that are in a particular state and whose duration is longer than 1 clock tick:

```
MSTATE == 1 && NTICK > 1
```

er_print Command Examples

This section provides some examples for using the `er_print` command.

EXAMPLE 12 Show Summary of How Time Is Spent in Functions

```
er_print -functions test.1.er
```

EXAMPLE 13 Show Caller-Callee Relationships

```
er_print -callers-callees test.1.er
```

EXAMPLE 14 Show Which Source Lines Are Hot

Source-line information assumes the code was compiled and linked with `-g`. Append a trailing underscore to the function name for Fortran functions and routines. The `1` after the function name is used to distinguish between multiple instances of `myfunction`.

```
er_print -source  myfunction 1 test.1.er
```

EXAMPLE 15 Filter Functions Named `myfunc` From the User Function Stack:

```
er_print -filters 'FNAME("myfunc") SOME IN USTACK' -functions test.1.er
```

EXAMPLE 16 Generate Output Similar to `gprof`

The following example generates a `gprof`-like list from an experiment. The output is a file named `er_print.out` which lists the top 100 functions, followed by caller-callee data sorted by attributed user time for each.

```
er_print -outfile  er_print.out -metrics e.%user -sort e.user \
-limit 100 -func -callers-callees test.1.er
```

You can also simplify this example into the following independent commands. However, keep in mind that each call to `er_print` in a large experiment or application can be time intensive.

```
er_print -metrics  e.%user -limit 100  -functions test.1.er

er_print -metrics  e.%user -callers-callees test.1.er
```

EXAMPLE 17 Show Only the Compiler Commentary

You do not have to run your program in order to use this command.

```
er_src -myfile.o
```

EXAMPLE 18 Use Wall-Clock Profiling to List Functions and Callers-Callees

```
er_print -metrics  ei.%wall -functions test.1.er

er_print -metrics aei.%wall  -callers-callees test.1.er
```

EXAMPLE 19 Run a Script Containing `er_print` Commands

```
er_print -script myscriptfile test.1.er
```

The `myscriptfile` script contains `er_print` commands. A sample of the script file contents follows:

```
## myscriptfile

## Send script output to standard output
outfile -

## Display descriptive information about the experiments
header

## Write out the sample data for all experiments
overview

## Write out execution statistics, aggregated over
## the current sample set for all experiments
statistics

## List functions
functions

## Display status and names of available load objects
object_list


## Write out annotated disassembly code for systime,
## to file disasm.out
```

```
outfile disasm.out
disasm systime


## Write out annotated source code for synprog.c
## to file source.out
outfile source.out
source synprog.c

## Terminate processing of the script
quit
```

♦ ♦ ♦ CHAPTER 6

Understanding Performance Analyzer and Its Data

The Performance Analyzer reads the event data that is collected by the Collector and converts it into performance metrics. The metrics are computed for various elements in the structure of the target program, such as instructions, source lines, functions, and load objects. In addition to a header containing a timestamp, thread ID, LWP ID, and CPU ID, the data recorded for each event collected has two parts:

- Some event-specific data that is used to compute metrics
- A call stack of the application that is used to associate those metrics with the program structure

The process of associating the metrics with the program structure is not always straightforward due to the insertions, transformations, and optimizations made by the compiler. This chapter describes the process and discusses the effect on what you see in the Performance Analyzer displays.

This chapter covers the following topics:

- "How Data Collection Works" on page 193
- "Interpreting Performance Metrics" on page 197
- "Call Stacks and Program Execution" on page 203
- "Mapping Addresses to Program Structure" on page 217
- "Mapping Performance Data to Index Objects" on page 225
- "Mapping Performance Data to Memory Objects" on page 226
- "Mapping Data Addresses to Program Data Objects" on page 226

How Data Collection Works

The output from a data collection run is an experiment, which is stored as a directory with various internal files and subdirectories in the file system.

Experiment Format

All experiments must have three files:

- A log file (`log.xml`), an XML file that contains information about what data was collected, the versions of various components, a record of various events during the life of the target, and the word size of the target
- A map file (`map.xml`), an XML file that records the time-dependent information about what load objects are loaded into the address space of the target, and the times at which they are loaded or unloaded
- An overview file, which is a binary file containing usage information recorded at every sample point in the experiment

In addition, experiments have binary data files representing the profile events in the life of the process. Each data file has a series of events, as described in "Interpreting Performance Metrics" on page 197. Separate files are used for each type of data, but each file is shared by all threads in the target.

For clock profiling or hardware counter overflow profiling, the data is written in a signal handler invoked by the clock tick or counter overflow. For synchronization tracing, heap tracing, I/O tracing, MPI tracing, or OpenMP tracing, data is written from `libcollector` routines that are interposed by the `LD_PRELOAD` environment variable on the normal user-invoked routines. Each such interposition routine partially fills in a data record, then invokes the normal user-invoked routine, and fills in the rest of the data record when that routine returns, and writes the record to the data file.

All data files are memory-mapped and written in blocks. The records are filled in such a way as to always have a valid record structure, so that experiments can be read as they are being written. The buffer management strategy is designed to minimize contention and serialization between threads.

An experiment can optionally contain an ASCII file with the name `notes`. This file is automatically created when using the `-C` *comment* argument to the `collect` command. You can create or edit the file manually after the experiment has been created. The contents of the file are prepended to the experiment header.

`archives` Directory

Each experiment has an `archives` directory that contains binary files describing each load object referenced in the `map.xml` file. These files are produced by the `er_archive` utility, which runs at the end of data collection. If the process terminates abnormally, the `er_archive` utility might not be invoked, in which case, the archive files are written by the `er_print` utility or Performance Analyzer when first invoked on the experiment.

Archive directories can also include copies of shared objects or of source files, depending on the options used to archive the experiment.

Subexperiments

Subexperiments are created when multiple processes are profiled, such as when you follow descendant processes, collect an MPI experiment, or profile the kernel with user processes.

Descendant processes write their experiments into subdirectories within the founder-experiment directory. These new subexperiments are named to indicate their lineage as follows:

- An underscore is appended to the creator's experiment name.
- One of the following code letters is added: `f` for fork, `x` for exec, and `c` for other descendants. On Linux, `C` is used for a descendant generated by `clone`(2).
- A number to indicate the index of the fork or exec is added after the code letter. .
- The experiment suffix, `.er` is appended to complete the experiment name.

For user processes, if the experiment name for the founder process is `test.1.er`, the experiment for the descendant process created by its third fork is `test.1.er/_f3.er`. If that descendant process executes a new image, the corresponding experiment name is `test.1.er/_f3_x1.er`. Descendant experiments consist of the same files as the parent experiment, but they do not have descendant experiments (all descendants are represented by subdirectories in the founder experiment), and they do not have archive subdirectories (all archiving is done into the founder experiment).

Experiments on the kernel by default are named `ktest.1.er` rather than `test.1.er`. When data is also collected on user processes, the kernel experiment contains subexperiments for each user process being followed. The kernel subexperiments are named using the format *_process-name*`_PID_`*process-id*`.1.er`. For example an experiment run on a `sshd` process running under process ID 1264 would be named `ktest.1.er/_sshd_PID_1264.1.er`.

Data for MPI programs are collected by default into `test.1.er`, and all the data from the MPI processes are collected into subexperiments, one per rank. The Collector uses the MPI rank to construct a subexperiment name with the form `M_r`*m*`.er`, where *m* is the MPI rank. For example, MPI rank 1 would have its experiment data recorded in the `test.1.er/M_r1.er` directory.

Dynamic Functions

An experiment where the target creates dynamic functions has additional records in the `map.xml` file describing those functions. An additional file, `dyntext`, contains a copy of the actual instructions of the dynamic functions. The copy is needed to produce annotated disassembly of dynamic functions.

Java Experiments

A Java experiment has additional records in the `map.xml` file, both for dynamic functions created by the JVM software for its internal purposes and for dynamically compiled (HotSpot) versions of the target Java methods.

In addition, a Java experiment includes a `JAVA_CLASSES` file, containing information about all of the user's Java classes invoked.

Java tracing data is recorded using a JVMTI agent, which is part of `libcollector.so`. The agent receives events that are mapped into the recorded trace events. The agent also receives events for class loading and HotSpot compilation, that are used to write the `JAVA_CLASSES` file, and the Java-compiled method records in the `map.xml` file.

Recording Experiments

You can record an experiment on a user-mode target in three different ways:

- With the `collect` command
- With `dbx` creating a process
- With `dbx` creating an experiment from a running process

The Profile Application dialog in Performance Analyzer runs a `collect` experiment.

`collect` Experiments

When you use the `collect` command to record an experiment, the `collect` utility creates the experiment directory and sets the `LD_PRELOAD` environment variable to ensure that `libcollector.so` and other `libcollector` modules are preloaded into the target's address space. The `collect` utility then sets environment variables to inform `libcollector.so` about the experiment name, and data collection options, and executes the target on top of itself.

`libcollector.so` and associated modules are responsible for writing all experiment files.

`dbx` Experiments That Create a Process

When `dbx` is used to launch a process with data collection enabled, `dbx` also creates the experiment directory and ensures preloading of `libcollector.so`. Then `dbx` stops the process at a breakpoint before its first instruction, and calls an initialization routine in `libcollector.so` to start the data collection.

Java experiments can not be collected by `dbx`, because `dbx` uses a Java Virtual Machine Debug Interface (JVMDI) agent for debugging. That agent can not coexist with the Java Virtual Machine Tools Interface (JVMTI) agent needed for data collection.

`dbx` Experiments on a Running Process

When `dbx` is used to start an experiment on a running process, it creates the experiment directory but cannot use the `LD_PRELOAD` environment variable. `dbx` makes an interactive function call into the target to open `libcollector.so`, and then calls the `libcollector.so` initialization routine, just as it does when creating the process. Data is written by `libcollector.so` and its modules just as in a collect experiment.

Because `libcollector.so` was not in the target address space when the process started, any data collection that depends on interposition on user-callable functions (synchronization tracing, heap tracing, MPI tracing) might not work. In general, the symbols have already been resolved to the underlying functions so the interposition can not happen. Furthermore, the following of descendant processes also depends on interposition, and does not work properly for experiments created by `dbx` on a running process.

If you have explicitly preloaded `libcollector.so` before starting the process with `dbx` or before using `dbx` to attach to the running process, you can collect tracing data.

Interpreting Performance Metrics

The data for each event contains a high-resolution timestamp, a thread ID, and a CPU ID. These can be used to filter the metrics in the Performance Analyzer by time, thread, or CPU. See the `getcpuid`(2) man page for information about CPU IDs. On systems where `getcpuid` is not available, the processor ID is -1, which maps to Unknown.

In addition to the common data, each event generates specific raw data, which is described in the following sections. Each section also contains a discussion of the accuracy of the metrics derived from the raw data and the effect of data collection on the metrics.

Clock Profiling

The event-specific data for clock profiling consists of an array of profiling interval counts. On Oracle Solaris, an interval counter is provided. At the end of the profiling interval, the appropriate interval counter is incremented by 1, and another profiling signal is scheduled. The array is recorded and reset only when the Solaris thread enters CPU user mode. Resetting the array consists of setting the array element for the User-CPU state to 1, and the array elements for all the other states to 0. The array data is recorded on entry to user mode before the array is reset. Thus, the array contains an accumulation of counts for each microstate that was entered since the previous entry into user mode for each of the ten microstates maintained by the kernel for each Solaris thread. On the Linux operating system, microstates do not exist. The only interval counter is User CPU Time.

The call stack is recorded at the same time as the data. If the Solaris thread is not in user mode at the end of the profiling interval, the call stack cannot change until the thread enters user mode again. Thus, the call stack always accurately records the position of the program counter at the end of each profiling interval.

The metrics to which each of the microstates contributes on Oracle Solaris are shown in Table 13, "How Kernel Microstates Contribute to Metrics," on page 198.

TABLE 13 How Kernel Microstates Contribute to Metrics

Kernel Microstate	Description	Metric Name
`LMS_USER`	Running in user mode	User CPU Time
`LMS_SYSTEM`	Running in system call or page fault	System CPU Time
`LMS_TRAP`	Running in any other trap	System CPU Time
`LMS_TFAULT`	Asleep in user text page fault	Text Page Fault Time
`LMS_DFAULT`	Asleep in user data page fault	Data Page Fault Time
`LMS_KFAULT`	Asleep in kernel page fault	Other Wait Time
`LMS_USER_LOCK`	Asleep waiting for user-mode lock	User Lock Time
`LMS_SLEEP`	Asleep for any other reason	Other Wait Time
`LMS_STOPPED`	Stopped (`/proc`, job control, or `lwp_stop`)	Other Wait Time
`LMS_WAIT_CPU`	Waiting for CPU	Wait CPU Time

Accuracy of Timing Metrics

Timing data is collected on a statistical basis, and is therefore subject to all the errors of any statistical sampling method. For very short runs in which only a small number of profile packets is recorded, the call stacks might not represent the parts of the program which consume the most resources. Run your program for long enough or for enough times to accumulate hundreds of profile packets for any function or source line you are interested in.

In addition to statistical sampling errors, specific errors arise from the way the data is collected and attributed and the way the program progresses through the system. The following are some of the circumstances in which inaccuracies or distortions can appear in the timing metrics:

- When a thread is created, the time spent before the first profile packet is recorded is less than the profiling interval but the entire profiling interval is ascribed to the microstate recorded in the first profile packet. If many threads are created, the error can be many times the profiling interval.
- When a thread is destroyed, some time is spent after the last profile packet is recorded. If many threads are destroyed, the error can be many times the profiling interval.
- Rescheduling of threads can occur during a profiling interval. As a consequence, the recorded state of the thread might not represent the microstate in which it spent most of the profiling interval. The errors are likely to be larger when there are more threads to run than there are processors to run them.
- A program can behave in a way that is correlated with the system clock. In this case, the profiling interval always expires when the thread is in a state that might represent a small fraction of the time spent and the call stacks recorded for a particular part of the program are overrepresented. On a multiprocessor system, the profiling signal can induce a correlation: processors that are interrupted by the profiling signal while they are running threads for the program are likely to be in the Trap-CPU microstate when the microstate is recorded.
- The kernel records the microstate value when the profiling interval expires. When the system is under heavy load, that value might not represent the true state of the process. On Oracle Solaris, this situation is likely to result in over accounting of the Trap-CPU or Wait-CPU microstate.
- When the system clock is being synchronized with an external source, the timestamps recorded in profile packets do not reflect the profiling interval but include any adjustment that was made to the clock. The clock adjustment can make it appear that profile packets are lost. The time period involved is usually several seconds, and the adjustments are made in increments.
- Experiments recorded on machines that dynamically change their operating clock frequency might reflect inaccuracies in profiling.

In addition to the inaccuracies just described, timing metrics are distorted by the process of collecting data. The time spent recording profile packets never appears in the metrics for the program because the recording is initiated by the profiling signal. (This is another instance of correlation.) The user CPU time spent in the recording process is distributed over whatever microstates are recorded. The result is an under-accounting of the User CPU Time metric and an over-accounting of other metrics. The amount of time spent recording data is typically less than a few percent of the CPU time for the default profiling interval.

Comparisons of Timing Metrics

If you compare timing metrics obtained from the profiling done in a clock-based experiment with times obtained by other means, you should be aware of the following issues.

For a single-threaded application, the total thread time recorded for a process is usually accurate to a few tenths of a percent, compared with the values returned by `gethrtime`(3C) for the same process. The CPU time can vary by several percentage points from the values returned by `gethrvtime`(3C) for the same process. Under heavy load, the variation might be even more pronounced. However, the CPU time differences do not represent a systematic distortion. The relative times reported for different functions, source-lines, and such are not substantially distorted.

The thread times that are reported in the Performance Analyzer can differ substantially from the times that are reported by `vmstat`, because `vmstat` reports times that are summed over CPUs. If the target process has more LWPs than the system on which it is running has CPUs, the Performance Analyzer shows more wait time than `vmstat` reports.

The microstate timings that appear in the Statistics view of the Performance Analyzer and the `er_print` statistics display are based on process file system `/proc` usage reports, for which the times spent in the microstates are recorded to high accuracy. See the `proc` (4) man page for more information. You can compare these timings with the metrics for the `<Total>` function, which represents the program as a whole, to gain an indication of the accuracy of the aggregated timing metrics. However, the values displayed in the Statistics view can include other contributions that are not included in the timing metric values for `<Total>`. These contributions come from the periods of time in which data collection is paused.

User CPU time and hardware counter cycle time differ because the hardware counters are turned off when the CPU mode has been switched to system mode. For more information, see “Traps” on page 205.

Hardware Counter Overflow Profiling

Hardware counter overflow profiling data includes a counter ID and the overflow value. The value can be larger than the value at which the counter is set to overflow because the processor executes some instructions between the overflow and the recording of the event. The value is especially likely to be larger for cycle and instruction counters, which are incremented much more frequently than counters such as floating-point operations or cache misses. The delay in recording the event also means that the program counter address recorded with call stack does not correspond exactly to the overflow event. See “Attribution of Hardware Counter Overflows” on page 243 for more information. See also the discussion of “Traps” on page 205. Traps and trap handlers can cause significant differences between reported User CPU time and time reported by the cycle counter.

Experiments recorded on machines that dynamically change their operating clock frequency might show inaccuracies in the conversion of cycle-based count to time.

The amount of data collected depends on the overflow value. Choosing a value that is too small can have the following consequences:

- The amount of time spent collecting data can be a substantial fraction of the execution time of the program. The collection run might spend most of its time handling overflows and writing data instead of running the program.
- A substantial fraction of the counts can come from the collection process. These counts are attributed to the collector function `collector_record_counters` . If you see high counts for this function, the overflow value is too small.
- The collection of data can alter the behavior of the program. For example, if you are collecting data on cache misses, the majority of the misses could come from flushing the collector instructions and profiling data from the cache and replacing it with the program instructions and data. The program would appear to have a lot of cache misses, but without data collection few cache misses might actually have occurred.

Dataspace Profiling and Memoryspace Profiling

A memoryspace profile is a profile in which memory-related events such as cache misses, are reported against the physical structures of the machine, such as cache-lines, memory-banks, or pages.

A dataspace profile is a profile in which those memory-related events, are reported against the data structures whose references cause the events rather than just the instructions where the memory-related events occur. Dataspace profiling is only available on SPARC systems running Oracle Solaris. It is not yet available on x86 systems running either Oracle Solaris or Linux.

For either memoryspace or dataspace profiling, the data collected must be hardware counter profiles using a memory-based counter. For precise counters, on either SPARC or x86 Oracle Solaris platforms, memoryspace and dataspace data is collected by default.

In order to support dataspace profiling, executables should be compiled with the `-xhwcprof` flag. This flag is applicable to compiling with the C, C++ and Fortran compilers, but is only meaningful on SPARC platforms. The flag is ignored on other platforms. If executables are not compiled with `-xhwcprof`, the `data_layout`, `data_single`, and `data_objects` commands from `er_print` will not show the data. Memoryspace profiling does not require `-xhwcprof` for precise counters.

When an experiment includes a dataspace or memoryspace profile, the `er_print` utility allows three additional commands: `data_objects`, `data_single`, and `data_layout`, as well as various commands relating to memory objects. See "Commands That Control the Dataspace List" on page 165 for more information.

In addition, the Performance Analyzer includes two views related to dataspace profiling and various tabs for memory objects. See "DataObjects View" on page 123 and "DataLayout View" on page 123 and "MemoryObjects Views" on page 122.

Running `collect -h` with no additional arguments lists hardware counters, and specifies whether they are load, store, or load-store related and whether they are precise. See "Hardware Counter Profiling Data" on page 28.

Synchronization Wait Tracing

The Collector collects synchronization delay events by tracing calls to the functions in the threads library, `libthread.so`, or to the real-time extensions library, `librt.so`. The event-specific data consists of high-resolution timestamps for the request and the grant (beginning and end of the call that is traced), and the address of the synchronization object (the mutex lock being requested, for example). The thread and LWP IDs are the IDs at the time the data is recorded. The wait time is the difference between the request time and the grant time. Only events for which the wait time exceeds the specified threshold are recorded. The synchronization wait tracing data is recorded in the experiment at the time of the grant.

The waiting thread cannot perform any other work until the event that caused the delay is completed. The time spent waiting appears both as Synchronization Wait Time and as User Lock Time. User Lock Time can be larger than Synchronization Wait Time because the synchronization delay threshold screens out delays of short duration.

The wait time is distorted by the overhead for data collection. The overhead is proportional to the number of events collected. You can minimize the fraction of the wait time spent in overhead by increasing the threshold for recording events.

Heap Tracing

The Collector records tracing data for calls to the memory allocation and deallocation functions `malloc`, `realloc`, `memalign`, and `free` by interposing on these functions. If your program bypasses these functions to allocate memory, tracing data is not recorded. Tracing data is not recorded for Java memory management, which uses a different mechanism.

The functions that are traced could be loaded from any of a number of libraries. The data that you see in Performance Analyzer might depend on the library from which a given function is loaded.

If a program makes a large number of calls to the traced functions in a short space of time, the time taken to execute the program can be significantly lengthened. The extra time is used in recording the tracing data.

I/O Tracing

The Collector records tracing data for calls to the standard I/O routines and all I/O system calls.

MPI Tracing

MPI tracing is based on a modified VampirTrace data collector. For more information, search for the VampirTrace User Manual on the Technische Universität Dresden web site.

Call Stacks and Program Execution

A *call stack* is a series of program counter addresses (PCs) representing instructions from within the program. The first PC, called the *leaf PC*, is at the bottom of the stack, and is the address of the next instruction to be executed. The next PC is the address of the call to the function containing the leaf PC. The next PC is the address of the call to that function, and so forth, until the top of the stack is reached. Each such address is known as a return address. The process of recording a call stack involves obtaining the return addresses from the program stack and is referred to as *unwinding the stack*. For information on unwind failures, see “Incomplete Stack Unwinds” on page 216.

The leaf PC in a call stack is used to assign exclusive metrics from the performance data to the function in which that PC is located. Each PC on the stack, including the leaf PC, is used to assign inclusive metrics to the function in which it is located.

Most of the time, the PCs in the recorded call stack correspond in a natural way to functions as they appear in the source code of the program, and the Performance Analyzer’s reported metrics correspond directly to those functions. Sometimes, however, the actual execution of the program does not correspond to a simple intuitive model of how the program would execute, and the Performance Analyzer's reported metrics might be confusing. See “Mapping Addresses to Program Structure” on page 217 for more information about such cases.

Single-Threaded Execution and Function Calls

The simplest case of program execution is that of a single-threaded program calling functions within its own load object.

When a program is loaded into memory to begin execution, a context is established for it that includes the initial address to be executed, an initial register set, and a stack (a region of memory used for scratch data and for keeping track of how functions call each other). The initial address is always at the beginning of the function `_start()`, which is built into every executable.

When the program runs, instructions are executed in sequence until a branch instruction is encountered, which among other things could represent a function call or a conditional statement. At the branch point, control is transferred to the address given by the target of the branch, and execution proceeds from there. (On SPARC, usually the next instruction after the branch is already committed for execution: this instruction is called the branch delay slot instruction. However, some branch instructions annul the execution of the branch delay slot instruction).

When the instruction sequence that represents a call is executed, the return address is put into a register, and execution proceeds at the first instruction of the function being called.

In most cases, somewhere in the first few instructions of the called function, a new frame (a region of memory used to store information about the function) is pushed onto the stack, and the return address is put into that frame. The register used for the return address can then be used when the called function itself calls another function. When the function is about to return, it pops its frame from the stack and control returns to the address from which the function was called.

Function Calls Between Shared Objects

When a function in one shared object calls a function in another shared object, the execution is more complicated than in a simple call to a function within the program. Each shared object contains a Program Linkage Table, or PLT, which contains entries for every function external to that shared object that is referenced from it. Initially the address for each external function in the PLT is actually an address within `ld.so`, the dynamic linker. The first time such a function is called, control is transferred to the dynamic linker, which resolves the call to the real external function and patches the PLT address for subsequent calls.

If a profiling event occurs during the execution of one of the three PLT instructions, the PLT PCs are deleted, and exclusive time is attributed to the call instruction. If a profiling event occurs during the first call through a PLT entry but the leaf PC is not one of the PLT instructions, any PCs that arise from the PLT and code in `ld.so` are attributed to an artificial function, `@plt`, which accumulates inclusive time. There is one such artificial function for each shared object. If the program uses the `LD_AUDIT` interface, the PLT entries might never be patched, and non-leaf PCs from `@plt` can occur more frequently.

Signals

When a signal is sent to a process, various register and stack operations occur that make it look as though the leaf PC at the time of the signal is the return address for a call to a system function, `sigacthandler()`. `sigacthandler()` calls the user-specified signal handler just as any function would call another.

Performance Analyzer treats the frames resulting from signal delivery as ordinary frames. The user code at the point at which the signal was delivered is shown as calling the system function `sigacthandler()`, and `sigacthandler()` in turn is shown as calling the user's signal handler. Inclusive metrics from both `sigacthandler()` and any user signal handler, and any other functions they call, appear as inclusive metrics for the interrupted function.

The Collector interposes on `sigaction()` to ensure that its handlers are the primary handlers for the `SIGPROF` signal when clock data is collected and `SIGEMT` signal when hardware counter overflow data is collected.

Traps

Traps can be issued by an instruction or by the hardware, and are caught by a trap handler. System traps are traps that are initiated from an instruction and trap into the kernel. All system calls are implemented using trap instructions. Some examples of hardware traps are those issued from the floating point unit when it is unable to complete an instruction, or when the instruction is not implemented in the hardware.

When a trap is issued, the kernel enters system mode. On Oracle Solaris, the microstate is usually switched from User CPU state to Trap state then to System state. The time spent handling the trap can show as a combination of System CPU time and User CPU time, depending on the point at which the microstate is switched. The time is attributed to the instruction in the user's code from which the trap was initiated (or to the system call).

For some system calls, providing as efficient handling of the call as possible is considered critical. The traps generated by these calls are known as *fast traps*. Among the system functions that generate fast traps are `gethrtime` and `gethrvtime`. In these functions, the microstate is not switched because of the overhead involved.

In other circumstances, providing as efficient handling of the trap as possible is also considered critical. Some examples of these are TLB (translation lookaside buffer) misses and register window spills and fills, for which the microstate is not switched.

In both cases, the time spent is recorded as User CPU time. However, the hardware counters are turned off because the CPU mode has been switched to system mode. The time spent handling these traps can therefore be estimated by taking the difference between User CPU time and Cycles time, preferably recorded in the same experiment.

In one case, the trap handler switches back to user mode, and that is the misaligned memory reference trap for an 8-byte integer which is aligned on a 4-byte boundary in Fortran. A frame for the trap handler appears on the stack, and a call to the handler can appear in the Performance Analyzer, attributed to the integer load or store instruction.

When an instruction traps into the kernel, the instruction following the trapping instruction appears to take a long time because it cannot start until the kernel has finished executing the trapping instruction.

Tail-Call Optimization

The compiler can do one particular optimization whenever the last thing a particular function does is to call another function. Rather than generating a new frame, the callee reuses the frame from the caller and the return address for the callee is copied from the caller. The motivation for this optimization is to reduce the size of the stack, and, on SPARC platforms, to reduce the use of register windows.

Suppose that the call sequence in your program source looks like this:

```
A -> B -> C -> D
```

When `B` and `C` are tail-call optimized, the call stack looks as if function `A` calls functions `B`, `C`, and `D` directly.

```
A -> B
A -> C
A -> D
```

The call tree is flattened. When code is compiled with the `-g` option, tail-call optimization takes place only at a compiler optimization level of 4 or higher. When code is compiled without the `-g` option, tail-call optimization takes place at a compiler optimization level of 2 or higher.

Explicit Multithreading

A simple program executes in a single thread. Multithreaded executables make calls to a thread creation function to which the target function for execution is passed. When the target exits, the thread is destroyed.

Oracle Solaris supports two thread implementations: Solaris threads and POSIX threads (Pthreads). Beginning with Oracle Solaris 10, both thread implementations are included in `libc.so`.

With Solaris threads, newly created threads begin execution at a function called `_thread_start()`, which calls the function passed in the thread creation call. For any call stack involving the target as executed by this thread, the top of the stack is `_thread_start()`, and there is no connection to the caller of the thread creation function. Inclusive metrics associated with the created thread therefore only propagate up as far as `_thread_start()` and the `<Total>` function. In addition to creating the threads, the Solaris threads implementation also creates LWPs on Oracle Solaris to execute the threads. Each thread is bound to a specific LWP.

Pthreads is available in Oracle Solaris as well as in Linux for explicit multithreading.

In both environments, to create a new thread, the application calls the Pthread API function `pthread_create()`, passing a pointer to an application-defined start routine as one of the function arguments.

On Oracle Solaris versions before Oracle Solaris 10 , when a new pthread starts execution, it calls the `_lwp_start()` function. Beginning with Oracle Solaris 10, `_lwp_start()` calls an intermediate function `_thrp_setup()`, which then calls the application-defined start routine that was specified in `pthread_create()`.

On the Linux operating system, when the new pthread starts execution, it runs a Linux-specific system function, `clone()`, which calls another internal initialization function, `pthread_start_thread()`, which in turn calls the application-defined start routine that was specified in `pthread_create()` . The Linux metrics-gathering functions available to the Collector are thread-specific. Therefore, when the `collect` utility runs, it interposes a metrics-gathering function, named `collector_root()`, between `pthread_start_thread()` and the application-defined thread start routine.

Overview of Java Technology-Based Software Execution

To the typical developer, a Java technology-based application runs just like any other program. The application begins at a main entry point, typically named `class.main`, which may call other methods just as a C or C++ application does.

To the operating system, an application written in the Java programming language, (pure or mixed with C/C++), runs as a process instantiating the JVM software. The JVM software is compiled from C++ sources and starts execution at `_start,` which calls `main`, and so forth. It reads bytecode from `.class` and/or `.jar` files, and performs the operations specified in that program. Among the operations that can be specified is the dynamic loading of a native shared object, and calls into various functions or methods contained within that object.

The JVM software does a number of things that are typically not done by applications written in traditional languages. At start-up, it creates a number of regions of dynamically generated code in its data space. One of these regions is the actual interpreter code used to process the application's bytecode methods.

During execution of a Java technology-based application, most methods are interpreted by the JVM software. These methods are referred to as *interpreted methods*. The Java HotSpot virtual machine monitors performance as it interprets the bytecode to detect methods that are frequently executed. Methods that are repeatedly executed might then be compiled by the Java HotSpot virtual machine to generate machine code for those methods. The resulting methods are referred to as *compiled methods*. The virtual machine executes the more efficient compiled methods thereafter, rather than interpreting the original bytecode for the methods. Compiled methods are loaded into the data space of the application, and may be unloaded at some later point in time. In addition, other code is generated in the data space to execute the transitions between interpreted and compiled code.

Code written in the Java programming language might also call directly into native-compiled code, either C, C++, or Fortran. he targets of such calls are referred to as native methods.

Applications written in the Java programming language are inherently multithreaded, and have one JVM software thread for each thread in the user's program. Java applications also have several housekeeping threads used for signal handling, memory management, and Java HotSpot virtual machine compilation.

Data collection is implemented with various methods in the JVMTI in J2SE.

Java Call Stacks and Machine Call Stacks

The performance tools collect their data by recording events in the life of each thread, along with the call stack at the time of the event. At any point in the execution of any application, the call stack represents where the program is in its execution, and how it got there. One important way that mixed-model Java applications differ from traditional C, C++, and Fortran applications is that at any instant during the run of the target two call stacks are meaningful: a Java call stack and a machine call stack. Both call stacks are recorded during profiling and are reconciled during analysis.

Clock Profiling and Hardware Counter Overflow Profiling

Clock profiling and hardware counter overflow profiling for Java programs work just as for C, C++, and Fortran programs, except that both Java call stacks and machine call stacks are collected.

Java Profiling View Modes

Performance Analyzer provides three view modes for displaying performance data for applications written in the Java programming language: User mode, Expert mode, and Machine mode. User mode is shown by default where the data supports it. The following section summarizes the main differences between these three view modes.

User View Mode of Java Profiling Data

User mode shows compiled and interpreted Java methods by name, and shows native methods in their natural form. During execution, many instances of a particular Java method might be executed: the interpreted version, and, perhaps, one or more compiled versions. In User mode all methods are shown aggregated as a single method. This view mode is selected in Performance Analyzer by default.

A PC for a Java method in the User view mode corresponds to the method-ID and a bytecode index into that method; a PC for a native function correspond to a machine PC. The call stack for a Java thread may have a mixture of Java PCs and machine PCs. It does not have any frames corresponding to Java housekeeping code, which does not have a Java representation. Under some circumstances, the JVM software cannot unwind the Java stack and a single frame with the special function, `<no Java callstack recorded>`, is returned. Typically, it amounts to no more than 5-10% of the total time.

The Functions view in User mode shows metrics against the Java methods and any native methods called. The Callers-Callees view shows the calling relationships in User mode.

Source for a Java method corresponds to the source code in the `.java` file from which it was compiled, with metrics on each source line. The disassembly of any Java method shows the bytecode generated for it, with metrics against each bytecode and interleaved Java source, where available.

The Timeline in the Java representation shows only Java threads. The call stack for each thread is shown with its Java methods.

Data space profiling in the Java representation is not currently supported.

Expert View Mode of Java Profiling Data

The Expert mode is similar to the User mode, except that some details of the JVM internals that are suppressed in the User mode are exposed in the Expert mode. With the Expert mode, the Timeline shows all threads. The call stack for housekeeping threads is a native call stack.

Machine View Mode of Java Profiling Data

The Machine mode shows functions from the JVM software itself, rather than from the application being interpreted by the JVM software. It also shows all compiled and native methods. The Machine mode looks the same as that of applications written in traditional languages. The call stack shows JVM frames, native frames, and compiled-method frames. Some of the JVM frames represent transition code between interpreted Java, compiled Java, and native code.

Source from compiled methods are shown against the Java source. The data represents the specific instance of the compiled-method selected. Disassembly for compiled methods shows the generated machine assembler code, not the Java bytecode. Caller-callee relationships show all overhead frames, and all frames representing the transitions between interpreted, compiled, and native methods.

The Timeline in the Machine view mode shows bars for all threads, LWPs, or CPUs, and the call stack in each is the Machine mode of the call stack.

Overview of OpenMP Software Execution

The actual execution model of OpenMP applications is described in the OpenMP specifications (See, for example, OpenMP Application Program Interface, Version 4.0, section 1.3.) The specification, however, does not describe some implementation details that might be important to users. The actual implementation from Oracle is such that directly recorded profiling information does not easily enable the user to understand how the threads interact.

As any single-threaded program runs, its call stack shows its current location and a trace of how it got there, starting from the beginning instructions in a routine called `_start`, which calls `main`, which then proceeds and calls various subroutines within the program. When a subroutine contains a loop, the program executes the code inside the loop repeatedly until the loop exit criterion is reached. The execution then proceeds to the next sequence of code, and so forth.

When the program is parallelized with OpenMP (as it is by autoparallelization), the behavior is different. An intuitive model of the parallelized program has the main, or master, thread executing just as a single-threaded program. When it reaches a parallel loop or parallel region, additional slave threads appear, each a clone of the master thread, with all of them executing the contents of the loop or parallel region in parallel, each for different chunks of work. When all chunks of work are completed, all the threads are synchronized, the slave threads disappear, and the master thread proceeds.

The actual behavior of the parallelized program is not so straightforward. When the compiler generates code for a parallel region or loop (or any other OpenMP construct), the code inside it is extracted and made into an independent function, called an *mfunction* in the Oracle implementation. (It may also be referred to as an outlined function, or a loop-body-function.) The name of the mfunction encodes the OpenMP construct type, the name of the function from which it was extracted, and the line number of the source line at which the construct appears. The names of these functions are shown in Performance Analyzer's Expert mode and Machine mode in the following form, where the name in brackets is the actual symbol-table name of the function:

```
bardo_ -- OMP parallel region from line 9 [_$p1C9.bardo_]
atomsum_ -- MP doall from line 7 [_$d1A7.atomsum_]
```

There are other forms of such functions, derived from other source constructs, for which the `OMP parallel region` in the name is replaced by `MP construct`, `MP doall`, or `OMP sections`. In the following discussion, all of these are referred to generically as *parallel regions*.

Each thread executing the code within the parallel loop can invoke its mfunction multiple times, with each invocation doing a chunk of the work within the loop. When all the chunks of work are complete, each thread calls synchronization or reduction routines in the library; the master thread then continues, while the slave threads become idle, waiting for the master thread to enter the next parallel region. All of the scheduling and synchronization are handled by calls to the OpenMP runtime.

During its execution, the code within the parallel region might be doing a chunk of the work, or it might be synchronizing with other threads or picking up additional chunks of work to do. It might also call other functions, which may in turn call still others. A slave thread (or the master thread) executing within a parallel region, might itself, or from a function it calls, act as a master thread, and enter its own parallel region, giving rise to nested parallelism.

Performance Analyzer collects data based on statistical sampling of call stacks, and aggregates its data across all threads and shows metrics of performance based on the type of data collected, against functions, callers and callees, source lines, and instructions. Performance Analyzer presents information on the performance of OpenMP programs in one of three view modes: User mode, Expert mode, and Machine mode.

For more detailed information about data collection for OpenMP programs, see An OpenMP Runtime API for Profiling (`http://www.oracle.com/technetwork/server-storage/solaris/omp-api-141059.html`).

User View Mode of OpenMP Profile Data

The User mode presentation of the profile data attempts to present the information as if the program really executed according to the intuitive model described in "Overview of OpenMP Software Execution" on page 210. The actual data, shown in the Machine mode, captures the implementation details of the runtime library, `libmtsk.so` , which does not correspond to the model. The Expert mode shows a mix of data altered to fit the model, and the actual data.

In User mode, the presentation of profile data is altered to match the model better, and differs from the recorded data and Machine mode presentation in the following ways:

- Artificial functions are constructed representing the state of each thread from the point of view of the OpenMP runtime library.
- Call stacks are manipulated to report data corresponding to the model of how the code runs, as described above.
- Two additional metrics of performance are constructed for clock profiling experiments, corresponding to time spent doing useful work and time spent waiting in the OpenMP runtime. The metrics are OpenMP Work and OpenMP Wait.
- For OpenMP 3.0 and 4.0 programs, a third metric, OpenMP Overhead, is constructed.

Artificial Functions

Artificial functions are constructed and put onto the User mode and Expert mode call stacks reflecting events in which a thread was in some state within the OpenMP runtime library.

The following artificial functions are defined:

`<OMP-overhead>`	Executing in the OpenMP library
`<OMP-idle>`	Slave thread, waiting for work
`<OMP-reduction>`	Thread performing a reduction operation
`<OMP-implicit_barrier>`	Thread waiting at an implicit barrier
`<OMP-explicit_barrier>`	Thread waiting at an explicit barrier
`<OMP-lock_wait>`	Thread waiting for a lock
`<OMP-critical_section_wait>`	Thread waiting to enter a critical section
`<OMP-ordered_section_wait>`	Thread waiting for its turn to enter an ordered section
`<OMP-atomic_wait>`	Thread waiting on an OpenMP atomic construct.

When a thread is in an OpenMP runtime state corresponding to one of the artificial functions, the artificial function is added as the leaf function on the stack. When a thread's actual leaf function is anywhere in the OpenMP runtime, it is replaced by `<OMP-overhead>` as the leaf function. Otherwise, all PCs from the OpenMP runtime are omitted from the user-mode stack.

For OpenMP 3.0 and 4.0 programs, the `<OMP-overhead>` artificial function is not used. The artificial function is replaced by an OpenMP Overhead metric.

User Mode Call Stacks

For OpenMP experiments, User mode shows reconstructed call stacks similar to those obtained when the program is compiled without OpenMP. The goal is to present profile data in a manner that matches the intuitive understanding of the program rather than showing all the details of the actual processing. The call stacks of the master thread and slave threads are reconciled and the artificial `<OMP-*>` functions are added to the call stack when the OpenMP runtime library is performing certain operations.

OpenMP Metrics

When processing a clock-profile event for an OpenMP program, two metrics corresponding to the time spent in each of two states in the OpenMP system are shown: OpenMP Work and OpenMP Wait.

Time is accumulated in OpenMP Work whenever a thread is executing from the user code, whether in serial or parallel. Time is accumulated in OpenMP Wait whenever a thread is waiting for something before it can proceed, whether the wait is a busy-wait (spin-wait), or sleeping. The sum of these two metrics matches the Total Thread metric in the clock profiles.

The OpenMP Wait and OpenMP Work metrics are shown in User mode, Expert mode, and Machine mode.

Expert View Mode of OpenMP Profiling Data

When you look at OpenMP experiments in Expert view mode you see the artificial functions of the form `<OMP-*>` when the OpenMP runtime is performing certain operations, similar to User view mode. However, Expert view mode separately shows compiler-generated mfunctions that represent parallelized loops, tasks, and so on. In User mode, these compiler-generated mfunctions are aggregated with user functions.

Machine View Mode of OpenMP Profiling Data

Machine mode shows native call stacks for all threads and outline functions generated by the compiler.

The real call stacks of the program during various phases of execution are quite different from the ones mentioned in the User model. The Machine mode shows the call stacks as measured, with no transformations done, and no artificial functions constructed. The clock-profiling metrics are, however, still shown.

In each of the call stacks below, `libmtsk` represents one or more frames in the call stack within the OpenMP runtime library. The details of which functions appear and in which order change from release to release of OpenMP, as does the internal implementation of code for a barrier or to perform a reduction.

1. Before the first parallel region

   Before the first parallel region is entered, there is only the one thread, the master thread. The call stack is identical to that in User mode and Expert mode.

Master
`foo`
`main`
`_start`

2. During execution in a parallel region

Master	Slave 1	Slave 2	Slave 3
`foo-OMP...`			
`libmtsk`			
`foo`	`foo-OMP...`	`foo-OMP...`	`foo-OMP...`
`main`	`libmtsk`	`libmtsk`	`libmtsk`
`_start`	`_lwp_start`	`_lwp_start`	`_lwp_start`

   In Machine mode, the slave threads are shown as starting in `_lwp_start` rather than in `_start` where the master starts. (In some versions of the thread library, that function may appear as `_thread_start` .) The calls to `foo-OMP...` represent the mfunctions that are generated for parallelized regions.

3. At the point at which all threads are at a barrier

Master	Slave 1	Slave 2	Slave 3
libmtsk			
foo-OMP...			
foo	libmtsk	libmtsk	libmtsk
main	foo-OMP...	foo-OMP...	foo-OMP...
_start	_lwp_start	_lwp_start	_lwp_start

Unlike when the threads are executing in the parallel region, when the threads are waiting at a barrier there are no frames from the OpenMP runtime between `foo` and the parallel region code, `foo-OMP...`. The reason is that the real execution does not include the OMP parallel region function, but the OpenMP runtime manipulates registers so that the stack unwind shows a call from the last-executed parallel region function to the runtime barrier code. Without it, there would be no way to determine which parallel region is related to the barrier call in Machine mode.

4. After leaving the parallel region

Master	Slave 1	Slave 2	Slave 3
foo			
main	libmtsk	libmtsk	libmtsk
_start	_lwp_start	_lwp_start	_lwp_start

In the slave threads, no user frames are on the call stack.

5. When in a nested parallel region

Master	Slave 1	Slave 2	Slave 3	Slave 4
	bar-OMP...			
foo-OMP...	libmtsk			
libmtsk	bar			
foo	foo-OMP...	foo-OMP...	foo-OMP...	bar-OMP...
main	libmtsk	libmtsk	libmtsk	libmtsk
_start	_lwp_start	_lwp_start	_lwp_start	_lwp_start

Incomplete Stack Unwinds

Stack unwind is defined in "Call Stacks and Program Execution" on page 203.

Stack unwind might fail for a number of reasons:

- If the stack has been corrupted by the user code. The program might core dump, or the data collection code might core dump, depending on exactly how the stack was corrupted.
- If the user code does not follow the standard ABI conventions for function calls. In particular, on the SPARC platform, if the return register, %o7, is altered before a save instruction is executed.

  On any platform, hand-written assembler code might violate the conventions.
- If the leaf PC is in a function after the callee's frame is popped from the stack but before the function returns.
- If the call stack contains more than about 250 frames, the Collector does not have the space to completely unwind the call stack. In this case, PCs for functions from `_start` to some point in the call stack are not recorded in the experiment. The artificial function `<Truncated-stack>` is shown as called from `<Total>` to tally the topmost frames recorded.
- If the Collector fails to unwind the frames of optimized functions on x86 platforms.

Intermediate Files

If you generate intermediate files using the `-E` or `-P` compiler options, Performance Analyzer uses the intermediate file for annotated source code, not the original source file. The `#line` directives generated with `-E` can cause problems in the assignment of metrics to source lines.

The following line appears in annotated source if there are instructions from a function that do not have line numbers referring to the source file that was compiled to generate the function:

function_name `-- <instructions without line numbers>`

Line numbers can be absent under the following circumstances:

- You compiled without specifying the `-g` option.
- The debugging information was stripped after compilation, or the executables or object files that contain the information are moved or deleted or subsequently modified.
- The function contains code that was generated from `#include` files rather than from the original source file.
- At high optimization, if code was inlined from a function in a different file.
- The source file has `#line` directives referring to some other file. This situation can occur if compiling with the `-E` option and then compiling the resulting `.i` file. It might also happen when you compile with the `-P` flag.

- The object file cannot be found to read line number information.
- The compiler used generates incomplete line number tables.

Mapping Addresses to Program Structure

Once a call stack is processed into PC values, the Analyzer maps those PCs to shared objects, functions, source lines, and disassembly lines (instructions) in the program. This section describes those mappings.

Process Image

When a program is run, a process is instantiated from the executable for that program. The process has a number of regions in its address space, some of which are text and represent executable instructions, and some of which are data that is not normally executed. PCs as recorded in the call stack normally correspond to addresses within one of the text segments of the program.

The first text section in a process derives from the executable itself. Others correspond to shared objects that are loaded with the executable, either at the time the process is started or dynamically loaded by the process. The PCs in a call stack are resolved based on the executable and shared objects loaded at the time the call stack was recorded. Executables and shared objects are very similar, and are collectively referred to as *load objects*.

Because shared objects can be loaded and unloaded in the course of program execution, any given PC might correspond to different functions at different times during the run. In addition, different PCs at different times might correspond to the same function, when a shared object is unloaded and then reloaded at a different address.

Load Objects and Functions

Each load object, whether an executable or a shared object, contains a text section with the instructions generated by the compiler, a data section for data, and various symbol tables. All load objects must contain an ELF symbol table, which gives the names and addresses of all the globally known functions in that object. Load objects compiled with the `-g` option contain additional symbolic information that can augment the ELF symbol table and provide information about functions that are not global, additional information about object modules from which the functions came, and line-number information relating addresses to source lines.

The term *function* is used to describe a set of instructions that represent a high-level operation described in the source code. The term covers subroutines as used in Fortran, methods as used in C++ and the Java programming language, and the like. Functions are described cleanly in the source code, and normally their names appear in the symbol table representing a set of addresses. If the program counter is within that set, the program is executing within that function.

In principle, any address within the text segment of a load object can be mapped to a function. Exactly the same mapping is used for the leaf PC and all the other PCs on the call stack. Most of the functions correspond directly to the source model of the program. The functions that do not are described in the following sections.

Aliased Functions

Typically, functions are defined as global, meaning that their names are known everywhere in the program. The name of a global function must be unique within the executable. If there is more than one global function of a given name within the address space, the runtime linker resolves all references to one of them. The others are never executed, and so do not appear in the function list. In the Selection Details window, you can see the shared object and object module that contain the selected function.

Under various circumstances, a function can be known by several different names. A very common example is the use of so-called weak and strong symbols for the same piece of code. A strong name is usually the same as the corresponding weak name except that it has a leading underscore. Many of the functions in the threads library also have alternate names for pthreads and Solaris threads, as well as strong and weak names and alternate internal symbols. In all such cases, only one name is used in the Functions view of Performance Analyzer. The name chosen is the last symbol at the given address in alphabetic order. This choice most often corresponds to the name that the user would use. In the Selection Details window, all the aliases for the selected function are shown.

Non-Unique Function Names

While aliased functions reflect multiple names for the same piece of code, under some circumstances, multiple pieces of code have the same name:

- Sometimes, for reasons of modularity, functions are defined as static, meaning that their names are known only in some parts of the program (usually a single compiled object module). In such cases, several functions of the same name referring to quite different parts of the program appear in Performance Analyzer. In the Selection Details window, the object module name for each of these functions is shown to distinguish them from one another. In addition, any selection of one of these functions can be used to show the source, disassembly, and the callers and callees of that specific function.

- Sometimes a program uses wrapper or interposition functions that have the weak name of a function in a library and supersede calls to that library function. Some wrapper functions call the original function in the library, in which case both instances of the name appear in Performance Analyzer's function list. Such functions come from different shared objects and different object modules, and can be distinguished from each other in that way. The Collector wraps some library functions, and both the wrapper function and the real function can appear in Performance Analyzer.

Static Functions From Stripped Shared Libraries

Static functions are often used within libraries, so that the name used internally in a library does not conflict with a name that you might use. When libraries are stripped, the names of static functions are deleted from the symbol table. In such cases, Performance Analyzer generates an artificial name for each text region in the library containing stripped static functions. The name is of the form `<static>@0x12345`, where the string following the `@` sign is the offset of the text region within the library. Performance Analyzer cannot distinguish between contiguous stripped static functions and a single such function, so two or more such functions can appear with their metrics coalesced.

Stripped static functions are shown as called from the correct caller, except when the PC from the static function is a leaf PC that appears after the save instruction in the static function. Without the symbolic information, Performance Analyzer does not know the save address, and cannot tell whether to use the return register as the caller. It always ignores the return register. Because several functions can be coalesced into a single `<static>@0x12345` function, the real caller or callee might not be distinguished from the adjacent functions.

Fortran Alternate Entry Points

Fortran provides a way of having multiple entry points to a single piece of code, enabling a caller to call into the middle of a function. When such code is compiled, it consists of a prologue for the main entry point, a prologue to the alternate entry point, and the main body of code for the function. Each prologue sets up the stack for the function’s eventual return and then branches or falls through to the main body of code.

The prologue code for each entry point always corresponds to a region of text that has the name of that entry point, but the code for the main body of the subroutine receives only one of the possible entry point names. The name received varies from one compiler to another.

The prologues rarely account for any significant amount of time, and the functions corresponding to entry points other than the one that is associated with the main body of the subroutine rarely appear in Performance Analyzer. Call stacks representing time in Fortran subroutines with alternate entry points usually have PCs in the main body of the subroutine rather than the prologue, and only the name associated with the main body appears as a callee. Likewise, all calls from the subroutine are shown as being made from the name associated with the main body of the subroutine.

Cloned Functions

The compilers have the ability to recognize calls to a function for which extra optimization can be performed. An example of such calls is a call to a function for which some of the arguments are constants. When the compiler identifies particular calls that it can optimize, it creates a copy of the function, which is called a clone, and generates optimized code. The clone function name is a mangled name that identifies the particular call. Performance Analyzer demangles the name and presents each instance of a cloned function separately in the function list. Each cloned function has a different set of instructions, so the annotated disassembly listing shows the cloned functions separately. Each cloned function has the same source code, so the annotated source listing sums the data over all copies of the function.

Inlined Functions

An inlined function is a function for which the instructions generated by the compiler are inserted at the call site of the function instead of an actual call. There are two kinds of inlining, both of which are done to improve performance, and both of which affect Performance Analyzer: C++ inline function definitions and explicit or automatic inlining.

- C++ inline function definitions. The rationale for inlining in this case is that the cost of calling a function is much greater than the work done by the inlined function, so inserting the code for the function at the call site is better than setting up a function call. Typically, access functions are defined to be inlined, because they often only require one instruction. When you compile with the `-g` option, inlining of functions is disabled. Compilation with `-g0` permits inlining of functions, and is recommended.
- Explicit or automatic inlining performed by the compiler at high optimization levels (4 and 5). Explicit and automatic inlining is performed even when `-g` is turned on. The rationale for this type of inlining can be to save the cost of a function call, but more often it is to provide more instructions for which register usage and instruction scheduling can be optimized.

Both kinds of inlining have the same effect on the display of metrics. Functions that appear in the source code but have been inlined do not show up in the function list, nor do they appear as callees of the functions into which they have been inlined. Metrics that would otherwise appear as inclusive metrics at the call site of the inlined function, representing time spent in the called function, are actually shown as exclusive metrics attributed to the call site, representing the instructions of the inlined function.

Note - Inlining can make data difficult to interpret, so you might want to disable inlining when you compile your program for performance analysis. Inlining of C++ access functions should not be disabled because it will lead to a high performance cost.

In some cases, even when a function is inlined, a so-called out-of-line function is left. Some call sites call the out-of-line function, but others have the instructions inlined. In such cases, the function appears in the function list but the metrics attributed to it represent only the out-of-line calls.

Compiler-Generated Body Functions

When a compiler parallelizes a loop in a function or a region that has parallelization directives, it creates new body functions that are not in the original source code. These functions are described in "Overview of OpenMP Software Execution" on page 210.

In user mode, Performance Analyzer does not show these functions. In expert and machine mode, Performance Analyzer shows these functions as normal functions, and assigns a name to them based on the function from which they were extracted, in addition to the compiler-generated name. Their exclusive metrics and inclusive metrics represent the time spent in the body function. In addition, the function from which the construct was extracted shows inclusive metrics from each of the body functions. This process is described in "Overview of OpenMP Software Execution" on page 210.

When a function containing parallel loops is inlined, the names of its compiler-generated body functions reflect the function into which it was inlined, not the original function.

Note - The names of compiler-generated body functions can be demangled only for modules compiled with `-g`.

Outline Functions

Outline functions can be created during feedback-optimized compilations. They represent code that is not normally executed, specifically code that is not executed during the training run used to generate the feedback for the final optimized compilation. A typical example is code that performs error checking on the return value from library functions; the error-handling code is never normally run. To improve paging and instruction-cache behavior, such code is moved elsewhere in the address space and is made into a separate function. The name of the outline function encodes information about the section of outlined code, including the name of the function from which the code was extracted and the line number of the beginning of the section in the source code. These mangled names can vary from release to release. Performance Analyzer provides a readable version of the function name.

Outline functions are not really called, but rather are jumped to. Similarly, they do not return, they jump back. In order to make the behavior more closely match the user's source code model, Performance Analyzer imputes an artificial call from the main function to its outline portion.

Outline functions are shown as normal functions, with the appropriate inclusive and exclusive metrics. In addition, the metrics for the outline function are added as inclusive metrics in the function from which the code was outlined.

For further details about feedback-optimized compilations, refer to the description of the `-xprofile` compiler option in one of the following manuals:

- Appendix B, "C Compiler Options Reference," in *Oracle Developer Studio 12.6: C User's Guide*
- Appendix A, "C++ Compiler Options," in *Oracle Developer Studio 12.6: C++ User's Guide*
- Chapter 3, "Fortran Compiler Options" in *Oracle Developer Studio 12.6: Fortran User's Guide*

Dynamically Compiled Functions

Dynamically compiled functions are functions that are compiled and linked while the program is executing. The Collector has no information about dynamically compiled functions that are written in C or C++ unless the user supplies the required information using the Collector API functions. See "Dynamic Functions and Modules" on page 57 for information about the API functions. If information is not supplied, the function appears in the performance analysis tools as `<Unknown>`.

For Java programs, the Collector obtains information on methods that are compiled by the Java HotSpot virtual machine. You do not need to use the API functions to provide the information. For other methods, the performance tools show information for the JVM software that executes the methods. In the Java representation, all methods are merged with the interpreted version. In the machine representation, each HotSpot-compiled version is shown separately, and JVM functions are shown for each interpreted method.

`<Unknown>` Function

Under some circumstances, a PC does not map to a known function. In such cases, the PC is mapped to a special function named `<Unknown>`.

The following circumstances show PCs mapping to `<Unknown>`:

- When a function written in C or C++ is dynamically generated, and information about the function is not provided to the Collector using the Collector API functions. See "Dynamic Functions and Modules" on page 57 for more information about the Collector API functions.
- When a Java method is dynamically compiled but Java profiling is disabled.
- When the PC corresponds to an address in the data section of the executable or a shared object. One case is the SPARC V7 version of `libc.so`, which has several functions in its data section (`.mul` and `.div`, for example). The code is in the data section so that it can be dynamically rewritten to use machine instructions when the library detects that it is executing on a SPARC V8 or SPARC V9 platform.
- When the PC corresponds to a shared object in the address space of the executable that is not recorded in the experiment.
- When the PC is not within any known load object. The most likely cause is an unwind failure, where the value recorded as a PC is not a PC at all but rather some other word. If the PC is the return register and it does not seem to be within any known load object, it is ignored rather than attributed to the `<Unknown>` function.
- When a PC maps to an internal part of the JVM software for which the Collector has no symbolic information.

Callers and callees of the `<Unknown>` function represent the previous and next PCs in the call stack, and are treated normally.

OpenMP Special Functions

Artificial functions are constructed and put onto the User mode call stacks reflecting events in which a thread was in some state within the OpenMP runtime library. The following artificial functions are defined:

`<OMP-overhead>`	Executing in the OpenMP library
`<OMP-idle>`	Slave thread, waiting for work
`<OMP-reduction>`	Thread performing a reduction operation
`<OMP-implicit_barrier>`	Thread waiting at an implicit barrier

`<OMP-explicit_barrier>`	Thread waiting at an explicit barrier
`<OMP-lock_wait>`	Thread waiting for a lock
`<OMP-critical_section_wait>`	Thread waiting to enter a critical section
`<OMP-ordered_section_wait>`	Thread waiting for its turn to enter an ordered section

`<JVM-System>` Function

In the User representation, the `<JVM-System>` function represents time used by the JVM software performing actions other than running a Java program. In this time interval, the JVM software is performing tasks such as garbage collection and HotSpot compilation. In user mode, `<JVM-System>` is visible in the Function list.

`<no Java callstack recorded>` Function

The `<no Java callstack recorded>` function is similar to the `<Unknown>` function, but for Java threads in the Java representation only. When the Collector receives an event from a Java thread, it unwinds the native stack and calls into the JVM software to obtain the corresponding Java stack. If that call fails for any reason, the event is shown in Performance Analyzer with the artificial function `<no Java callstack recorded>`. The JVM software might refuse to report a call stack either to avoid deadlock or when unwinding the Java stack would cause excessive synchronization.

`<Truncated-stack>` Function

The size of the buffer used by Performance Analyzer for recording the metrics of individual functions in the call stack is limited. If the size of the call stack becomes so large that the buffer becomes full, any further increase in size of the call stack will force Performance Analyzer to drop function profile information. Because in most programs the bulk of exclusive CPU time is spent in the leaf functions, Performance Analyzer drops the metrics for the less critical functions at the bottom of the stack, starting with the entry functions `_start()` and `main()`. The metrics for the dropped functions are consolidated into the single artificial `<Truncated-stack>` function. The `<Truncated-stack>` function may also appear in Java programs.

To support deeper stacks, set the `SP_COLLECTOR_STACKBUFSZ` environment variable to a larger number.

`<Total>` Function

The `<Total>` function is an artificial construct used to represent the program as a whole. All performance metrics, in addition to being attributed to the functions on the call stack, are attributed to the special function `<Total>` . The function appears at the top of the function list and its data can be used to give perspective on the data for other functions. In the Callers-Callees list, this function is shown as the nominal caller of `_start()` in the main thread of execution of any program, and also as the nominal caller of `_thread_start()` for created threads. If the stack unwind was incomplete, the `<Total>` function can appear as the caller of `<Truncated-stack>`.

Functions Related to Hardware Counter Overflow Profiling

The following functions are related to hardware counter overflow profiling:

- `collector_not_program_related` – The counter does not relate to the program.
- `collector_hwcs_out_of_range` – The counter appears to have exceeded the overflow value without generating an overflow signal. The value is recorded and the counter reset.
- `collector_hwcs_frozen` – The counter appears to have exceeded the overflow value and been halted but the overflow signal appears to be lost. The value is recorded and the counter reset.
- `collector_hwc_ABORT` – Reading the hardware counters has failed, typically when a privileged process has taken control of the counters, resulting in the termination of hardware counter collection.
- `collector_record_counter` – The counts accumulated while handling and recording hardware counter events, partially accounting for hardware counter overflow profiling overhead. If this value corresponds to a significant fraction of the `<Total>` count, a larger overflow interval (that is, a lower resolution configuration) is recommended.

Mapping Performance Data to Index Objects

Index objects represent sets of things whose index can be computed from the data recorded in each packet. Index-object sets that are predefined include Threads, CPUs, Samples, and Seconds. Other index objects can be defined through the `er_print indxobj_define` command, issued directly or in a `.er.rc` file. In Performance Analyzer, you can define index objects by selecting Settings from the Tools menu, selecting the Views tab, and clicking the Add Custom Index Object View button.

For each packet, the index is computed and the metrics associated with the packet are added to the Index Object at that index. An index of `-1` maps to the `<Unknown>` Index Object. All metrics for index objects are exclusive metrics, as no hierarchical representation of index objects is meaningful.

Mapping Performance Data to Memory Objects

Memory objects are components in the memory subsystem, such as cache-lines, pages, and memory-banks. The object is determined from an index computed from the virtual or physical address as recorded. Memory objects are predefined for virtual pages and physical pages, for sizes of 8 KB, 64 KB, 512 KB, and 4 MB. You can define others with the `mobj_define` command in the `er_print` utility. You can also define custom memory objects using the Add Memory Objects View button in Performance Analyzer's Settings dialog. See "Configuration Settings" on page 139for more information.

You can load a file that defines Memory Objects for a specific SPARC system architecture. Click the Load Machine Model button and select the system architecture of interest. Click Apply or OK and a new list of objects displays in the Memory Objects Views column. You can select from these views to display associated data. Search for "Machine Model" in the help for more information.

By default Performance Analyzer loads a machine model file that is appropriate for the machine on which an experiment was recorded. Machine model files can define both Memory Objects and Index Objects.

Mapping Data Addresses to Program Data Objects

Once a PC from a hardware counter event corresponding to a precise memory operation has been found, Performance Analyzer uses instruction identifiers and descriptors provided by the compiler in its hardware profiling support information to derive the associated program data object.

The term *data object* is used to refer to program constants, variables, arrays and aggregates such as structures and unions, along with distinct aggregate elements, described in source code. Depending on the source language, data object types and their sizes vary. Many data objects are explicitly named in source programs, while others may be unnamed. Some data objects are derived or aggregated from other (simpler) data objects, resulting in a rich, often complex, set of data objects.

Each data object has an associated scope, the region of the source program where it is defined and can be referenced. This scope might be global (such as a load object), a particular compilation unit (an object file), or a function. Identical data objects might be defined with different scopes, or particular data objects referred to differently in different scopes.

Data-derived metrics from hardware counter events for memory operations collected with backtracking enabled are attributed to the associated program data object type. These metrics propagate to any aggregates containing the data object and the artificial `<Total>`, which is considered to contain all data objects (including `<Unknown>` and `<Scalars>`). The different subtypes of `<Unknown>` propagate up to the `<Unknown>` aggregate. The following section describes the `<Total>`, `<Scalars>`, and `<Unknown>` data objects.

Data Object Descriptors

Data objects are fully described by a combination of their declared type and name. A simple scalar data object `{int i}` describes a variable called `i` of type `int`, while `{const+pointer+int p}` describes a constant pointer to a type `int` called `p`. Spaces in the type names are replaced with underscore (_), and unnamed data objects are represented with a name of dash (-), for example, `{double_precision_complex -}`.

An entire aggregate is similarly represented `{structure:foo_t}` for a structure of type `foo_t`. An element of an aggregate requires the additional specification of its container, for example, `{structure:foo_t}.{int i}` for a member `i` of type `int` of the previous structure of type `foo_t`. Aggregates can also themselves be elements of (larger) aggregates, with their corresponding descriptor constructed as a concatenation of aggregate descriptors and, ultimately, a scalar descriptor.

While a fully qualified descriptor might not always be necessary to disambiguate data objects, it provides a generic complete specification to assist with data object identification.

`<Total>` Data Object

The `<Total>` data object is an artificial construct used to represent the program's data objects as a whole. All performance metrics, in addition to being attributed to a distinct data object (and any aggregate to which it belongs), are attributed to the special data object `<Total>`. It appears at the top of the data object list. Its data can be used to give perspective to the data for other data objects.

`<Scalars>` Data Object

While aggregate elements have their performance metrics additionally attributed into the metric value for their associated aggregate, all of the scalar constants and variables have their performance metrics additionally attributed into the metric value for the artificial `<Scalars>` data object.

`<Unknown>` Data Object and Its Elements

Under various circumstances, event data can not be mapped to a particular data object. In such cases, the data is mapped to the special data object named `<Unknown>` and one of its elements as follows:

- Module with trigger PC not compiled with `-xhwcprof`

  No event-causing instruction or data object was identified because the object code was not compiled with hardware counter profiling support.
- Backtracking failed to find a valid branch target

  No event-causing instruction was identified because the hardware profiling support information provided in the compilation object was insufficient to verify the validity of backtracking.
- Backtracking traversed a branch target

  No event-causing instruction or data object was identified because backtracking encountered a control transfer target in the instruction stream.
- No identifying descriptor provided by the compiler

  The compiler did not provide data object information for the memory-referencing instruction.
- No type information

  The compiler did not identify the instruction as a memory-referencing instruction.
- Not determined from the symbolic information provided by the compiler

  The compiler did not have symbolic information for the instruction. Compiler temporaries are generally unidentified.
- Backtracking was prevented by a jump or call instruction

  No event-causing instructions were identified because backtracking encountered a branch or call instruction in the instruction stream.
- Backtracking did not find trigger PC

  No event-causing instructions were found within the maximum backtracking range.
- Could not determine VA because registers changed after trigger instruction

The virtual address of the data object was not determined because registers were overwritten during hardware counter skid.

- Memory-referencing instruction did not specify a valid VA

  The virtual address of the data object did not appear to be valid.

♦ ♦ ♦ CHAPTER 7

Understanding Annotated Source and Disassembly Data

Annotated source code and annotated disassembly code are useful for determining which source lines or instructions within a function are responsible for poor performance, and to view commentary on how the compiler has performed transformations on the code. This section describes the annotation process and some of the issues involved in interpreting the annotated code.

This chapter covers the following topics:

How the Tools Find Source Code

In order to display annotated source code and annotated disassembly code, Performance Analyzer and `er_print` utility must have access to the source code and load object files used by the program on which an experiment was run. If Performance Analyzer cannot find the source, you can click the Resolve button to provide the path to the source.

Load object files are first looked for in the `archives` directory of the experiment. If they are not found there, they are looked for using the same algorithm as source and object files, described below.

In most experiments, source and object files are recorded in the form of full paths. Java source files also have a package name which lists the directory structure to the file. If you view an experiment on the same system where it was recorded, the source files and load object can be found using the full paths. When experiments are moved or looked at on a different machine, those full paths might not be accessible.

Two complementary methods are used to locate source and object files: path mapping and searching a path. The same methods are used to find load object files if they are not found in the `archives` subdirectory.

You can set path maps and search paths to help the tools find the files referenced by your experiment. In Performance Analyzer, use the Settings dialog box to set path maps in the Pathmaps tab, and use the Search Path tab to set the search path as described in "Configuration Settings" on page 139. For the `er_print` utility, use the `pathmap` and `setpath` directives described in "Commands That Control Searching For Source Files" on page 164.

Path mapping is applied first and specifies how to replace the beginning of a full file path with a different path. For example, if a file is specified as `/a/b/c/sourcefile`, and a `pathmap` directive specifies mapping `/a/` to `/x/y/`, the file could be found in `/x/y/b/c/sourcefile`. A `pathmap` directive that maps `/a/b/c/` to `/x/`, would allow the file to be found in `/x/sourcefile`.

If path mapping does not find the file, the search path is used. The search path gives a list of directories to be searched for a file with the given base name, which is `sourcefile` in the example above. You can set the search path with the `setpath` command, and append a directory to the search path with the `addpath` command. For Java files the package name is tried and then the base name is tried.

Each directory in the search path is used to construct a full path to try. For Java source files two full paths are constructed, one for the base name and one for the package name. The tools apply the path mapping to each of the full paths and if none of the mapped paths point to the file, the next search path directory is tried.

If the file is not found in the search path and no path mapping prefix matched the original full path, the original full path is tried. If any path map prefix matched the original full path, but the file was not found, the original full path is not tried.

Note that the default search path includes the current directory and the experiment directories, so one way to make source files accessible is to copy them to either of those places, or to put symbolic links in those places pointing to the current location of the source file.

Annotated Source Code

Annotated source code for an experiment can be viewed in the Performance Analyzer by selecting the Source view in the left pane of Performance Analyzer window. Alternatively, annotated source code can be viewed without running an experiment, by using the `er_src` utility. This section of the manual describes how source code is displayed in the Performance Analyzer. For details on viewing annotated source code with the `er_src` utility, see "Viewing Source/Disassembly Without an Experiment" on page 250.

Annotated source in Performance Analyzer contains the following information:

- The contents of the original source file
- The performance metrics of each line of executable source code
- Highlighting of code lines with metrics exceeding a specific threshold
- Index lines
- Compiler commentary

Performance Analyzer Source View Layout

The Source view is divided into columns, with fixed-width columns for individual metrics on the left and the annotated source taking up the remaining width on the right.

Identifying the Original Source Lines

All lines displayed in black in the annotated source are taken from the original source file. The number at the start of a line in the annotated source column corresponds to the line number in the original source file. Any lines with characters displayed in a different color are either index lines or compiler commentary lines.

Index Lines in the Source View

A source file is any file compiled to produce an object file or interpreted into bytecode. An object file normally contains one or more regions of executable code corresponding to functions, subroutines, or methods in the source code. Performance Analyzer analyzes the object file, identifies each executable region as a function, and attempts to map the functions it finds in the object code to the functions, routines, subroutines, or methods in the source file associated with the object code. When Performance Analyzer succeeds, it adds an index line in the annotated source file in the location corresponding to the first instruction in the function found in the object code.

The annotated source shows an index line for every function, including inline functions, even though inline functions are not displayed in the list displayed by the Function view. The Source view displays index lines in red italics with text in angle-brackets. The simplest type of index line corresponds to the function's default context. The default source context for any function is defined as the source file to which the first instruction in that function is attributed. The following example shows an index line for a C function `icputime`.

```
                    578. int
                    579. icputime(int k)
0.       0.         580. {
```

```
                        <Function: icputime>
```

As the example shows, the index line appears on the line following the first instruction. For C source, the first instruction corresponds to the opening brace at the start of the function body. In Fortran source, the index line for each subroutine follows the line containing the `subroutine` keyword. Also, a `main` function index line follows the first Fortran source instruction executed when the application starts, as shown in the following example:

```
                       1. ! Copyright (c) 2006, 2010, Oracle and/or its affiliates. All
 Rights Reserved.
                       2. ! @(#)omptest.f 1.11 10/03/24 SMI
                       3. ! Synthetic f90 program, used for testing openmp directives
 and the
                       4. !      analyzer
                       5.
0.    0.    0.    0.   6.       program omptest
                                    <Function: MAIN>
                                   7.
                                   8. !$PRAGMA C (gethrtime, gethrvtime)
```

Sometimes, Performance Analyzer might not be able to map a function it finds in the object code with any programming instructions in the source file associated with that object code; for example, code may be `#included` or inlined from another file, such as a header file.

Also displayed in red are special index lines and other special lines that are not compiler commentary. For example, as a result of compiler optimization, a special index line might be created for a function in the object code that does not correspond to code written in any source file. For details, refer to "Special Lines in the Source, Disassembly and PCs Tabs" on page 244.

Compiler Commentary

Compiler commentary indicates how compiler-optimized code has been generated. Compiler commentary lines are displayed in blue to distinguish them from index lines and original source lines. Various parts of the compiler can incorporate commentary into the executable. Each comment is associated with a specific line of source code. When the annotated source is written, the compiler commentary for any source line appears immediately preceding the source line.

The compiler commentary describes many of the transformations which have been made to the source code to optimize it. These transformations include loop optimizations, parallelization, inlining and pipelining. The following example shows compiler commentary.

```
0.    0.    0.    0.     28.       SUBROUTINE dgemv_g2 (transa, m, n, alpha, b, ldb,   &
                         29.      &                   c, incc, beta, a, inca)
                         30.       CHARACTER (KIND=1) :: transa
                                  31.       INTEGER   (KIND=4) :: m, n, incc, inca, ldb
                                  32.       REAL      (KIND=8) :: alpha, beta
                                  33.       REAL      (KIND=8) :: a(1:m), b(1:ldb,1:n),
 c(1:n)
                                  34.       INTEGER            :: i, j
                                  35.       REAL      (KIND=8) :: tmr, wtime, tmrend
                                  36.       COMMON/timer/ tmr
                                  37.
                             Function wtime_ not inlined because the compiler has not
 seen
                             the body of the routine
0.    0.    0.    0.     38.       tmrend = tmr + wtime()


                             Function wtime_ not inlined because the compiler has not
 seen
                             the body of the routine
                             Discovered loop below has tag L16
0.    0.    0.    0.     39.       DO WHILE(wtime() < tmrend)

                          Array statement below generated loop L4
0.    0.    0.    0.     40.       a(1:m) = 0.0
                                  41.

                          Source loop below has tag L6
0.    0.    0.    0.     42.       DO j = 1, n       ! <=-----\ swapped loop indices

                          Source loop below has tag L5
                             L5 cloned for unrolling-epilog.  Clone is L19
                             All 8 copies of L19 are fused together as part of unroll
 and jam
                             L19 scheduled with steady-state cycle count = 9
                             L19 unrolled 4 times
                             L19 has 9 loads, 1 stores, 8 prefetches, 8 FPadds,
                             8 FPmuls, and 0 FPdivs per iteration
                             L19 has 0 int-loads, 0 int-stores, 11 alu-ops, 0 muls,
                             0 int-divs and 0 shifts per iteration
                             L5 scheduled with steady-state cycle count = 2
                             L5 unrolled 4 times
                             L5 has 2 loads, 1 stores, 1 prefetches, 1 FPadds, 1 FPmuls,
                             and 0 FPdivs per iteration
                             L5 has 0 int-loads, 0 int-stores, 4 alu-ops, 0 muls,
                             0 int-divs and 0 shifts per iteration
0.210 0.210 0.210 0.     43.          DO i = 1, m
4.003 4.003 4.003 0.050  44.             a(i) = a(i) + b(i,j) * c(j)
0.240 0.240 0.240 0.     45.          END DO
0.    0.    0.    0.     46.       END DO
                                  47.       END DO
                                  48.
```

```
0.    0.    0.    0.     49.        RETURN
0.    0.    0.    0.     50.        END
```

You can set the types of compiler commentary displayed in the Source view using the Source/Disassembly tab in the Settings dialog box; for details, see "Configuration Settings" on page 139.

Common Subexpression Elimination

One very common optimization recognizes that the same expression appears in more than one place, and that performance can be improved by generating the code for that expression in one place. For example, if the same operation appears in both the `if` and the `else` branches of a block of code, the compiler can move that operation to just before the `if` statement. When it does so, it assigns line numbers to the instructions based on one of the previous occurrences of the expression. If the line numbers assigned to the common code correspond to one branch of an `if` structure and the code actually always takes the other branch, the annotated source shows metrics on lines within the branch that is not taken.

Loop Optimizations

The compiler can do several types of loop optimization. Some of the more common ones are as follows:

- Loop unrolling
- Loop peeling
- Loop interchange
- Loop fission
- Loop fusion

Loop unrolling consists of repeating several iterations of a loop within the loop body, and adjusting the loop index accordingly. As the body of the loop becomes larger, the compiler can schedule the instructions more efficiently. Also reduced is the overhead caused by the loop index increment and conditional check operations. The remainder of the loop is handled using loop peeling.

Loop peeling consists of removing a number of loop iterations from the loop, and moving them in front of or after the loop, as appropriate.

Loop interchange changes the ordering of nested loops to minimize memory stride, in order to maximize cache-line hit rates.

Loop fusion consists of combining adjacent or closely located loops into a single loop. The benefits of loop fusion are similar to loop unrolling. In addition, if common data is accessed in the two pre-optimized loops, cache locality is improved by loop fusion, providing the compiler with more opportunities to exploit instruction-level parallelism.

Loop fission is the opposite of loop fusion: a loop is split into two or more loops. This optimization is appropriate if the number of computations in a loop becomes excessive, leading to register spills that degrade performance. Loop fission can also come into play if a loop contains conditional statements. Sometimes it is possible to split the loops into two: one with the conditional statement and one without. This approach can increase opportunities for software pipelining in the loop without the conditional statement.

Sometimes, with nested loops, the compiler applies loop fission to split a loop apart, and then performs loop fusion to recombine the loop in a different way to increase performance. In this case, you see compiler commentary similar to the following example:

```
Loop below fissioned into 2 loops
Loop below fused with loop on line 116
[116]    for (i=0;i<nvtxs;i++) {
```

Inlining of Functions

With an inline function, the compiler inserts the function instructions directly at the locations where it is called instead of making actual function calls. Thus, similar to a C/C++ macro, the instructions of an inline function are replicated at each call location. The compiler performs explicit or automatic inlining at high optimization levels (4 and 5).

Inlining saves the cost of a function call and provides more instructions for which register usage and instruction scheduling can be optimized, at the cost of a larger code footprint in memory. The following example shows inlining compiler commentary.

```
                Function initgraph inlined from source file ptralias.c
                    into the code for the following line
0.       0.         44.       initgraph(rows);
```

Note - The compiler commentary does not wrap onto two lines in the Source view of Performance Analyzer.

Parallelization

Code that contains Sun, Cray, or OpenMP parallelization directives can be compiled for parallel execution on multiple processors. The compiler commentary indicates where parallelization has and has not been performed, and why. The following example shows parallelization computer commentary.

```
0.       6.324       9. c$omp  parallel do shared(a,b,c,n) private(i,j,k)
                   Loop below parallelized by explicit user directive
                   Loop below interchanged with loop on line 12
0.010    0.010     [10]            do i = 2, n-1

                   Loop below not parallelized because it was nested in a parallel loop
                   Loop below interchanged with loop on line 12
0.170    0.170      11.               do j = 2, i
```

For more details about parallel execution and compiler-generated body functions, refer to "Overview of OpenMP Software Execution" on page 210.

Special Lines in the Annotated Source

Several other annotations for special cases can be shown under the Source view, either in the form of compiler commentary or as special lines displayed in the same color as index lines. For details, refer to "Special Lines in the Source, Disassembly and PCs Tabs" on page 244.

Source Line Metrics

Source code metrics are displayed, for each line of executable code, in fixed-width columns. The metrics are the same as in the function list. You can change the defaults for an experiment using a `.er.rc` file. For details, see "Setting Defaults in `.er.rc` Files" on page 182. You can also change the metrics displayed and the highlighting thresholds in Performance Analyzer using the Settings dialog box. For details, see "Configuration Settings" on page 139.

Annotated source code shows the metrics of an application at the source-line level. It is produced by taking the PCs (program counts) that are recorded in the application's call stack, and mapping each PC to a source line. To produce an annotated source file, Performance Analyzer first determines all of the functions that are generated in a particular object module (`.o` file) or load object, then scans the data for all PCs from each function.

In order to produce annotated source, Performance Analyzer must be able to find and read the object module or load object to determine the mapping from PCs to source lines. It must be able to read the source file to produce an annotated copy, which is displayed. See "How the Tools Find Source Code" on page 231 for a description of the process used to find an experiment's source code.

The compilation process goes through many stages, depending on the level of optimization requested, and transformations take place which can confuse the mapping of instructions to source lines. For some optimizations, source line information might be completely lost, while for others, it might be confusing. The compiler relies on various heuristics to track the source line for an instruction, and these heuristics are not infallible.

Interpreting Source Line Metrics

Metrics for an instruction must be interpreted as metrics accrued while waiting for the instruction to be executed. If the instruction being executed when an event is recorded comes from the same source line as the leaf PC, the metrics can be interpreted as due to execution of that source line. However, if the leaf PC comes from a different source line than the instruction being executed, at least some of the metrics for the source line that the leaf PC belongs to must be interpreted as metrics accumulated while this line was waiting to be executed. An example is when a value that is computed on one source line is used on the next source line.

For hardware-counter overflow profiling using a precise hardware counter (as indicated in the output from `collect -h`), the leaf PC is the PC of the instruction that causes the counter to overflow, not the next instruction to be executed. For non-precise hardware counters the leaf PC reported might be several instructions past the instruction that causes the overflow. This is because the kernel mechanism for recognizing when the overflow occurs has a variable amount of skid.

The issue of how to interpret the metrics matters most when a substantial delay occurs in execution, such as at a cache miss or a resource queue stall, or when an instruction is waiting for a result from a previous instruction. In such cases, the metrics for the source lines can seem to be unreasonably high. Look at other nearby lines in the code to find the line responsible for the high metric value.

Metric Formats

The four possible formats for the metrics that can appear on a line of annotated source code are explained in Table 14, "Annotated Source-Code Metrics," on page 239.

TABLE 14 Annotated Source-Code Metrics

Metric	Significance
(Blank)	No PC in the program corresponds to this line of code. This case should always apply to comment lines, and applies to apparent code lines in the following circumstances: ■ All the instructions from the apparent piece of code have been eliminated during optimization. ■ The code is repeated elsewhere, and the compiler performed common subexpression recognition and tagged all the instructions with the lines for the other copy. ■ The compiler tagged an instruction from that line with an incorrect line number.
`0.`	Some PCs in the program were tagged as derived from this line, but no data referred to those PCs: they were never in a call stack that was sampled statistically or traced. The `0.` metric does not indicate that the line was not executed, only that it did not show up statistically in a profiling data packet or a recorded tracing data packet.
`0.000`	At least one PC from this line appeared in the data, but the computed metric value rounded to zero.
`1.234`	The metrics for all PCs attributed to this line added up to the non-zero numerical value shown.

Annotated Disassembly Code

Annotated disassembly provides an assembly-code listing of the instructions of a function or object module with the performance metrics associated with each instruction. Annotated disassembly can be displayed in several ways, determined by whether line number mappings and the source file are available, and whether the object module for the function whose annotated disassembly is being requested is known.

- If the object module is not known, Performance Analyzer disassembles the instructions for just the specified function, and does not show any source lines in the disassembly.
- If the object module is known, the disassembly covers all functions within the object module.
- If the source file is available and line number data is recorded, Performance Analyzer can interleave the source with the disassembly, depending on the display preference.
- If the compiler has inserted any commentary into the object code, it too is interleaved in the disassembly if the corresponding preferences are set.

Each instruction in the disassembly code is annotated with the following information:

- A source line number, as reported by the compiler
- Its relative address
- The hexadecimal representation of the instruction, if requested
- The assembler ASCII representation of the instruction

Where possible, call addresses are resolved to symbols (such as function names). Metrics are shown on the lines for instructions. They can be shown on any interleaved source code if the corresponding preference is set. Possible metric values are as described for source-code annotations in Table 14, “Annotated Source-Code Metrics,” on page 239.

The disassembly listing for code that is `#included` in multiple locations repeats the disassembly instructions once for each time that the code has been `#included`. The source code is interleaved only for the first time a repeated block of disassembly code is shown in a file. For example, if a block of code defined in a header called `inc_body.h` is `#included` by four functions named `inc_body` , `inc_entry`, `inc_middle`, and `inc_exit`, then the block of disassembly instructions appears four times in the disassembly listing for `inc_body.h`, but the source code is interleaved only in the first of the four blocks of disassembly instructions. Switching to Source view reveals index lines corresponding to each of the times that the disassembly code was repeated.

Index lines can be displayed in the Disassembly view. Unlike with the Source view, these index lines cannot be used directly for navigation purposes. Placing the cursor on one of the instructions immediately below the index line and selecting the Source view navigates you to the file referenced in the index line.

Files that `#include` code from other files show the included code as raw disassembly instructions without interleaving the source code. Placing the cursor on one of these instructions and selecting the Source view opens the file containing the `#include`d code. Selecting the Disassembly view with this file displayed shows the disassembly code with interleaved source code.

Source code can be interleaved with disassembly code for inline functions but not for macros.

When code is not optimized, the line numbers for each instruction are in sequential order, and the interleaving of source lines and disassembled instructions occurs in the expected way. When optimization takes place, instructions from later lines sometimes appear before those from earlier lines. The Analyzer's algorithm for interleaving is that whenever an instruction is shown as coming from line *N*, all source lines up to and including line *N* are written before the instruction. One effect of optimization is that source code can appear between a control transfer instruction and its delay slot instruction. Compiler commentary associated with line *N* of the source is written immediately before that line.

Interpreting Annotated Disassembly

Interpreting annotated disassembly is not straightforward. The leaf PC is the address of the next instruction to execute, so metrics attributed to an instruction should be considered as time spent waiting for the instruction to execute. However, the execution of instructions does not always happen in sequence, and delays might occur in the recording of the call stack. To make use of annotated disassembly, you should become familiar with the hardware on which you record your experiments and the way in which it loads and executes instructions.

The next few subsections discuss some of the issues of interpreting annotated disassembly.

Instruction Issue Grouping

Instructions are loaded and issued in groups known as instruction issue groups. Which instructions are in the group depends on the hardware, the instruction type, the instructions already being executed, and any dependencies on other instructions or registers. As a result, some instructions might be underrepresented because they are always issued in the same clock cycle as the previous instruction so they never represent the next instruction to be executed. When the call stack is recorded, there might be several instructions that could be considered the next instruction to execute.

Instruction issue rules vary from one processor type to another, and depend on the instruction alignment within cache lines. Because the linker forces instruction alignment at a finer granularity than the cache line, changes in a function that might seem unrelated can cause different alignment of instructions. The different alignment can cause a performance improvement or degradation.

The following artificial situation shows the same function compiled and linked in slightly different circumstances. The two output examples shown below are the annotated disassembly listings from the `er_print` utility. The instructions for the two examples are identical, but the instructions are aligned differently.

In the following output example the instruction alignment maps the two instructions `cmp` and `bl,a` to different cache lines. A significant amount of time is used waiting to execute these two instructions.

```
   Excl.     Incl.
User CPU  User CPU
    sec.      sec.
                             1. static int
                             2. ifunc()
                             3. {
                             4.     int i;
                             5.
                             6.     for (i=0; i<10000; i++)
                                <function: ifunc>
   0.010     0.010              [ 6]    1066c:  clr         %o0
   0.        0.                 [ 6]    10670:  sethi       %hi(0x2400), %o5
   0.        0.                 [ 6]    10674:  inc         784, %o5
                             7.         i++;
   0.        0.                 [ 7]    10678:  inc         2, %o0
## 1.360     1.360              [ 7]    1067c:  cmp         %o0, %o5
## 1.510     1.510              [ 7]    10680:  bl,a        0x1067c
   0.        0.                 [ 7]    10684:  inc         2, %o0
   0.        0.                 [ 7]    10688:  retl
   0.        0.                 [ 7]    1068c:  nop
                             8.     return i;
                             9. }
```

In the following output example, the instruction alignment maps the two instructions `cmp` and `bl,a` to the same cache line. A significant amount of time is used waiting to execute only one of these instructions.

```
   Excl.     Incl.
User CPU  User CPU
    sec.      sec.
                             1. static int
                             2. ifunc()
                             3. {
                             4.     int i;
                             5.
                             6.     for (i=0; i<10000; i++)
```

```
                                   <function: ifunc>
   0.         0.                   [ 6]    10684:  clr         %o0
   0.         0.                   [ 6]    10688:  sethi       %hi(0x2400), %o5
   0.         0.                   [ 6]    1068c:  inc         784, %o5
                                7.         i++;
   0.         0.                   [ 7]    10690:  inc         2, %o0
## 1.440      1.440                [ 7]    10694:  cmp         %o0, %o5
   0.         0.                   [ 7]    10698:  bl,a        0x10694
   0.         0.                   [ 7]    1069c:  inc         2, %o0
   0.         0.                   [ 7]    106a0:  retl
   0.         0.                   [ 7]    106a4:  nop
                                8.     return i;
                                9. }
```

Instruction Issue Delay

Sometimes, specific leaf PCs appear more frequently because the instruction that they represent is delayed before issue. This appearance can occur for a number of reasons, some of which are listed below:

- The previous instruction takes a long time to execute and is not interruptible, for example when an instruction traps into the kernel.
- An arithmetic instruction needs a register that is not available because the register contents were set by an earlier instruction that has not yet completed. An example of this sort of delay is a load instruction that has a data cache miss.
- A floating-point arithmetic instruction is waiting for another floating-point instruction to complete. This situation occurs for instructions that cannot be pipelined, such as square root and floating-point divide.
- The instruction cache does not include the memory word that contains the instruction (I-cache miss).

Attribution of Hardware Counter Overflows

Apart from TLB misses on some platforms and `precise` counters, the call stack for a hardware counter overflow event is recorded at some point further on in the sequence of instructions than the point at which the overflow occurred. This delay occurs for various reasons including the time taken to handle the interrupt generated by the overflow. For some counters, such as cycles or instructions issued, this delay does not matter. For other counters, such as those counting cache misses or floating point operations, the metric is attributed to a different instruction from that which is responsible for the overflow.

Often the PC that caused the event is only a few instructions before the recorded PC, and the instruction can be correctly located in the disassembly listing. However, if a branch target is within this instruction range, it might be difficult or impossible to determine which instruction corresponds to the PC that caused the event.

Systems that have processors with counters that are labeled with the `precise` keyword allow memoryspace profiling without any special compilation of binaries. For example the SPARC T4 and M7 processors provide several `precise` counters. Run the `collect -h` command and look for the `memoryspace` keyword to determine if your system allows memoryspace profiling.

Special Lines in the Source, Disassembly and PCs Tabs

Performance Analyzer displays some lines in the Source, Disassembly and PCs views that do not directly correspond to lines of code, instructions, or program counters. The following sections describe these special lines.

Outline Functions

Outline functions can be created during feedback-optimized compilations. They are displayed as special index lines in the Source view and Disassembly view. In the Source view, an annotation is displayed in the block of code that has been converted into an outline function.

```
                   Function binsearchmod inlined from source file ptralias2.c into the
0.       0 .         58.         if( binsearchmod( asize, &element ) ) {
0.240    0.240       59.             if( key != (element << 1) ) {
0.       0.          60.                 error |= BINSEARCHMODPOSTESTFAILED;
                        <Function: main -- outline code from line 60 [_$o1B60.main]>
0.040    0.040     [ 61]                 break;
0.       0.          62.             }
0.       0.          63.         }
```

In the Disassembly view, the outline functions are typically displayed at the end of the file.

```
                        <Function: main -- outline code from line 85 [_$o1D85.main]>
0.       0.             [ 85] 100001034:  sethi       %hi(0x100000), %i5
0.       0.             [ 86] 100001038:  bset        4, %i3
0.       0.             [ 85] 10000103c:  or          %i5, 1, %l7
0.       0.             [ 85] 100001040:  sllx        %l7, 12, %l5
0.       0.             [ 85] 100001044:  call        printf ! 0x100101300
0.       0.             [ 85] 100001048:  add         %l5, 336, %o0
0.       0.             [ 90] 10000104c:  cmp         %i3, 0
0.       0.             [ 20] 100001050:  ba,a        0x1000010b4
                        <Function: main -- outline code from line 46 [_$o1A46.main]>
0.       0.             [ 46] 100001054:  mov         1, %i3
0.       0.             [ 47] 100001058:  ba          0x100001090
```

```
0.       0.             [ 56] 10000105c:  clr         [%i2]
                        <Function: main -- outline code from line 60 [_$o1B60.main]>
0.       0.             [ 60] 100001060:  bset        2, %i3
0.       0.             [ 61] 100001064:  ba          0x10000109c
0.       0.             [ 74] 100001068:  mov         1, %o3
```

The name of the outline function is displayed in square brackets, and encodes information about the section of outlined code, including the name of the function from which the code was extracted and the line number of the beginning of the section in the source code. These mangled names can vary from release to release. Performance Analyzer provides a readable version of the function name. For further details, refer to “Outline Functions” on page 221.

If an outline function is called when collecting the performance data for an application, Performance Analyzer displays a special line in the annotated disassembly to show inclusive metrics for that function. For further details, see “Inclusive Metrics” on page 250.

Compiler-Generated Body Functions

When a compiler parallelizes a loop in a function or a region that has parallelization directives, it creates new body functions that are not in the original source code. These functions are described in “Overview of OpenMP Software Execution” on page 210.

The compiler assigns mangled names to body functions that encode the type of parallel construct, the name of the function from which the construct was extracted, the line number of the beginning of the construct in the original source, and the sequence number of the parallel construct. These mangled names vary from release to release of the microtasking library, but are shown demangled into more comprehensible names.

The following example shows a typical compiler-generated body function as displayed in the functions list in machine mode.

```
7.415      14.860      psec_ -- OMP sections from line 9 [_$s1A9.psec_]
3.873       3.903      craydo_ -- MP doall from line 10 [_$d1A10.craydo_]
```

In the examples, the name of the function from which the construct was extracted is shown first, followed by the type of parallel construct, followed by the line number of the parallel construct, followed by the mangled name of the compiler-generated body function in square brackets. Similarly, in the disassembly code, a special index line is generated.

```
0.       0.            <Function: psec_ -- OMP sections from line 9 [_$s1A9.psec_]>
0.       7.445         [24]    1d8cc:  save        %sp, -168, %sp
0.       0.            [24]    1d8d0:  ld          [%i0], %g1
0.       0.            [24]    1d8d4:  tst         %i1

0.       0.            <Function: craydo_ -- MP doall from line 10 [_$d1A10.craydo_]>
```

```
0.       0.030         [ ?]    197e8:  save        %sp, -128, %sp
0.       0.            [ ?]    197ec:  ld          [%i0 + 20], %i5
0.       0.            [ ?]    197f0:  st          %i1, [%sp + 112]
0.       0.            [ ?]    197f4:  ld          [%i5], %i3
```

With Cray directives, the function may not be correlated with source code line numbers. In such cases, a `[ ?]` is displayed in place of the line number. If the index line is shown in the annotated source code, the index line indicates instructions without line numbers, as shown in the following example.

```
                     9. c$mic  doall shared(a,b,c,n) private(i,j,k)

                   Loop below fused with loop on line 23
                   Loop below not parallelized because autoparallelization
                     is not enabled
                   Loop below autoparallelized
                   Loop below interchanged with loop on line 12
                   Loop below interchanged with loop on line 12
3.873     3.903         <Function: craydo_ -- MP doall from line 10 [_$d1A10.craydo_],
                      instructions without line numbers>
0.        3.903     10.           do i = 2, n-1
```

Note - Index lines and compiler-commentary lines do not wrap in the real displays.

Dynamically Compiled Functions

Dynamically compiled functions are functions that are compiled and linked while the program is executing. The Collector has no information about dynamically compiled functions that are written in C or C++, unless the user supplies the required information using the Collector API function `collector_func_load()`. Information displayed by the Function view, Source view, and Disassembly view depends on the information passed to `collector_func_load()` as follows:

- If information is not supplied, `collector_func_load()` is not called. The dynamically compiled and loaded function appears in the function list as `<Unknown>`. Neither function source nor disassembly code is viewable in Performance Analyzer.
- If no source file name and no line-number table is provided but the name of the function, its size, and its address are provided, the name of the dynamically compiled and loaded function and its metrics appear in the function list. The annotated source is available, and the disassembly instructions are viewable, although the line numbers are specified by `[?]` to indicate that they are unknown.
- If the source file name is given but no line-number table is provided, the information displayed by Performance Analyzer is similar to the case where no source file name is given

except that the beginning of the annotated source displays a special index line indicating that the function is composed of instructions without line numbers. For example:

```
1.121     1.121          <Function func0, instructions without line numbers>
                      1. #include        <stdio.h>
```

- If the source file name and line-number table is provided, the function and its metrics are displayed by the Function view, Source view, and Disassembly view in the same way as conventionally compiled functions.

For more information about the Collector API functions, see "Dynamic Functions and Modules" on page 57.

For Java programs, most methods are interpreted by the JVM software. The Java HotSpot virtual machine, running in a separate thread, monitors performance during the interpretive execution. During the monitoring process, the virtual machine might decide to take one or more interpreted methods, generate machine code for them, and execute the more-efficient machine-code version, rather than interpret the original.

For Java programs,you do not need to use the Collector API functions. Performance Analyzer signifies the existence of Java HotSpot-compiled code in the annotated disassembly listing using a special line underneath the index line for the method, as shown in the following example.

```
                   11.    public int add_int () {
                   12.       int       x = 0;
2.832     2.832      <Function: Routine.add_int: HotSpot-compiled leaf instructions>
0.        0.         [ 12] 00000000: iconst_0
0.        0.         [ 12] 00000001: istore_1
```

The disassembly listing only shows the interpreted bytecode, not the compiled instructions. By default, the metrics for the compiled code are shown next to the special line. The exclusive and inclusive CPU times are different than the sum of all the inclusive and exclusive CPU times shown for each line of interpreted bytecode. In general, if the method is called on several occasions, the CPU times for the compiled instructions are greater than the sum of the CPU times for the interpreted bytecode This discrepancy occurs because the interpreted code is executed only once when the method is initially called, whereas the compiled code is executed thereafter.

The annotated source does not show Java HotSpot-compiled functions. Instead, it displays a special index line to indicate instructions without line numbers. For example, the annotated source corresponding to the disassembly extract in the previous example is as follows:

```
                     11.    public int add_int () {
2.832     2.832        <Function: Routine.add_int(), instructions without line numbers>
0.        0.         12.       int       x = 0;
                       <Function: Routine.add_int()>
```

Java Native Functions

Native code is compiled code originally written in C, C++, or Fortran, called using the Java Native Interface (JNI) by Java code. The following example is taken from the annotated disassembly of file `jsynprog.java` associated with demo program `jsynprog`.

```
                     5. class jsynprog
                        <Function: jsynprog.<init>()>
0.       5.504          jsynprog.JavaCC() <Java native method>
0.       1.431          jsynprog.JavaCJava(int) <Java native method>
0.       5.684          jsynprog.JavaJavaC(int) <Java native method>
0.       0.             [  5] 00000000: aload_0
0.       0.             [  5] 00000001: invokespecial <init>()
0.       0.             [  5] 00000004: return
```

Because the native methods are not included in the Java source, the beginning of the annotated source for `jsynprog.java` shows each Java native method using a special index line to indicate instructions without line numbers.

```
0.       5.504          <Function: jsynprog.JavaCC(), instructions without line
                           numbers>
0.       1.431          <Function: jsynprog.JavaCJava(int), instructions without line
                           numbers>
0.       5.684          <Function: jsynprog.JavaJavaC(int), instructions without line
                           numbers>
```

Note - The index lines do not wrap in the real annotated source display.

Cloned Functions

The compilers have the ability to recognize calls to a function for which extra optimization can be performed, for example, a call to a function where some of the arguments passed are constants. When the compiler identifies particular calls that it can optimize, it creates a copy of the function, which is called a clone, and generates optimized code.

In the annotated source, compiler commentary indicates if a cloned function has been created:

```
0.       0.       Function foo from source file clone.c cloned,
                   creating cloned function _$c1A.foo;
                   constant parameters propagated to clone
0.       0.570     27.    foo(100, 50, a, a+50, b);
```

Note - Compiler commentary lines do not wrap in the real annotated source display.

The clone function name is a mangled name that identifies the particular call. In the previous example, the compiler commentary indicates that the name of the cloned function is `_$c1A.foo`. This function can be seen in the function list as follows:

```
0.350     0.550     foo
0.340     0.570     _$c1A.foo
```

Each cloned function has a different set of instructions, so the annotated disassembly listing shows the cloned functions separately. They are not associated with any source file, and therefore the instructions are not associated with any source line numbers. The following example shows the first few lines of the annotated disassembly for a cloned function.

```
0.       0.           <Function: _$c1A.foo>
0.       0.           [?]    10e98:  save        %sp, -120, %sp
0.       0.           [?]    10e9c:  sethi       %hi(0x10c00), %i4
0.       0.           [?]    10ea0:  mov         100, %i3
0.       0.           [?]    10ea4:  st          %i3, [%i0]
0.       0.           [?]    10ea8:  ldd         [%i4 + 640], %f8
```

Static Functions

Static functions are often used within libraries, so that the name used internally in a library does not conflict with a name that the user might use. When libraries are stripped, the names of static functions are deleted from the symbol table. In such cases, Performance Analyzer generates an artificial name for each text region in the library containing stripped static functions. The name is of the form `<static>@0x12345`, where the string following the `@` sign is the offset of the text region within the library. Performance Analyzer cannot distinguish between contiguous stripped static functions and a single such function, so two or more such functions can appear with their metrics coalesced. The following example shows static functions in the functions list of a sample `jsynprog` demo.

```
0.       0.       <static>@0x18780
0.       0.       <static>@0x20cc
0.       0.       <static>@0xc9f0
0.       0.       <static>@0xd1d8
0.       0.       <static>@0xe204
```

In the PCs view, these functions are represented with an offset, as follows:

```
0.       0.       <static>@0x18780 + 0x00000818
0.       0.       <static>@0x20cc + 0x0000032C
0.       0.       <static>@0xc9f0 + 0x00000060
0.       0.       <static>@0xd1d8 + 0x00000040
0.       0.       <static>@0xe204 + 0x00000170
```

An alternative representation in the PCs view of functions called within a stripped library is:

```
<library.so> -- no functions found + 0x0000F870
```

Inclusive Metrics

In the annotated disassembly, special lines exist to tag the time taken by outline functions.

The following example shows the annotated disassembly displayed when an outline function is called:

```
0.       0.        43.         else
0.       0.        44.         {
0.       0.        45.                 printf("else reached\n");
0.       2.522         <inclusive metrics for outlined functions>
```

Annotations for Store and Load Instructions

When you compile with the `-xhwcprof` option, the compilers generate additional information for store (`st`) and load (`ld`) instructions. You can view the annotated `st` and `ld` instructions in disassembly listings.

Branch Target

When you compile with the `-xhwcprof` option, an artificial line, `<branch target>`, shown in the annotated disassembly listing, corresponds to a PC of an instruction which can be reached from more than one code path.

Viewing Source/Disassembly Without an Experiment

You can view annotated source code and annotated disassembly code using the `er_src` utility, without running an experiment. The display is generated in the same way as in Performance Analyzer, except that it does not display any metrics. The syntax of the `er_src` command is as follows:

`er_src [ -func | -{source,src}` *item tag* `| -{disasm,dis}` *item tag* `|`
`-{cc,scc,dcc}` *com-spec* `| -outfile` *filename* `| -V ]` *object*

object is the name of an executable, a shared object, or an object file (`.o` file).

item is the name of a function or of a source or object file used to build the executable or shared object. *item* can also be specified in the form *function'file'*, in which case `er_src` displays the source or disassembly of the named function in the source context of the named file.

tag is an index used to determine which *item* is being referred to when multiple functions have the same name. It is required, but is ignored if not necessary to resolve the function.

The special item and tag, `all -1`, tells `er_src` to generate the annotated source or disassembly for all functions in the object.

Note - The output generated as a result of using `all -1` on executables and shared objects may be very large.

The following sections describe the options accepted by the `er_src` utility.

`-func`

List all the functions from the given object.

`-{source,src}` *item tag*

Show the annotated source for the listed item.

`-{disasm,dis}` *item tag*

Include the disassembly in the listing. The default listing does not include the disassembly. If no source is available, a listing of the disassembly without compiler commentary is produced.

`-{cc,scc,dcc}` *com-spec*

Specify which classes of compiler commentary classes to show. *com-spec* is a list of classes separated by colons. The *com-spec* is applied to source compiler commentary if the `-scc` option is used, to disassembly commentary if the `-dcc` option is used, or to both source and disassembly commentary if `-cc` is used. See "Commands That Control the Source and Disassembly Listings" on page 160 for a description of these classes.

The commentary classes can be specified in a defaults file. The system wide `er.rc` defaults file is read first, then an `.er.rc` file in the user's home directory, if present, then an `.er.rc` file in the current directory. Defaults from the `.er.rc` file in your home directory override the system defaults, and defaults from the `.er.rc` file in the current directory override both home and system defaults. These files are also used by Performance Analyzer and the `er_print` utility, but only the settings for source and disassembly compiler commentary are used by the `er_src` utility. See "Setting Defaults in `.er.rc` Files" on page 182 for a description of the defaults files. Commands in a defaults file other than `scc` and `dcc` are ignored by the `er_src` utility.

`-outfile` *filename*

Open the file *filename* for output of the listing. By default, or if the filename is a dash (-), output is written to `stdout`.

`-V`

Print the current release version.

♦ ♦ ♦ CHAPTER 8

Manipulating Experiments

This chapter describes the utilities which are available for use with the Collector and Performance Analyzer.

This chapter covers the following topics:

Manipulating Experiments

Experiments are stored in a directory that is created by the Collector. To manipulate experiments, you can use the usual UNIX® commands `cp`, `mv` and `rm` and apply them to the directory. You cannot do so for experiments from releases earlier than Forte Developer 7 (Sun™ ONE Studio 7, Enterprise Edition for Solaris). Three utilities which behave like the UNIX commands have been provided to copy, move, and delete experiments. These utilities are `er_cp`(1), `er_mv`(1) and `er_rm`(1).They are described below.

The data in the experiment includes archive files for each of the load objects used by your program. These archive files contain the absolute path of the load object and the date on which it was last modified. This information is not changed when you move or copy an experiment.

Copying Experiments With the `er_cp` Utility

Two forms of the `er_cp` command exist:

```
er_cp [-V] experiment1 experiment2
er_cp [-V] experiment-list directory
```

The first form of the `er_cp` command copies *experiment1* to *experiment2*. If *experiment2* exists, `er_cp` exits with an error message. The second form copies a blank-separated list of experiments to a directory. If the directory already contains an experiment with the same name as one of the experiments being copied the `er_cp` utility exits with an error message. The `-V` option prints the version of the `er_cp` utility. This command does not copy experiments created with earlier versions of the tools.

Moving Experiments With the `er_mv` Utility

Two forms of the `er_mv` command exist:

`er_mv [-V]` *experiment1 experiment2*
`er_mv [-V]` *experiment-list directory*

The first form of the `er_mv` command moves *experiment1* to *experiment2*. If *experiment2* exists, the `er_mv` utility exits with an error message. The second form moves a blank-separated list of experiments to a directory. If the directory already contains an experiment with the same name as one of the experiments being moved, the `er_mv` utility exits with an error message. The `-V` option prints the version of the `er_mv` utility. This command does not move experiments created with earlier versions of the tools. For more information, see `er_mv`(1).

Deleting Experiments With the `er_rm` Utility

The `er_rm` utility removes a list of experiments or experiment groups. When experiment groups are removed, each experiment in the group is removed, then the group file is removed.

The syntax of the `er_rm` command is as follows:

`er_rm [-f] [-V]` *experiment-list*

The `-f` option suppresses error messages and ensures successful completion, regardless of whether the experiments are found. The `-V` option prints the version of the `er_rm` utility. This command removes experiments created with earlier releases of the tools. For more information, see `er_rm`(1).

Labeling Experiments

The `er_label` command enables you to define part of an experiment and assign a name or label to it. The label captures the profiling events that occur during one or more periods of time in the experiment that you define with start time and stop time markers.

You can specify time markers as the current time, the current time plus or minus a time offset, or as an offset relative to the start time of the experiment. Any number of time intervals can specified in a label, and additional intervals can be added to a label after it is created.

The `er_label` utility expects that intervals are specified with pairs of markers: a start time followed by a stop time. The utility ignores markers that occur out of sequence, such as a stop marker specified before any start marker, a start marker that follows a previous start marker with no intervening stop marker, or a stop marker that follows a previous stop marker with no intervening start marker.

You can assign labels to experiments by running the `er_label` command at the command line or by executing it in scripts. Once you have added labels to an experiment, you can use the labels for filtering. For example, you might filter the experiment to include or exclude the profiling events in the time periods defined by the label as described in "Using Labels for Filtering" on page 134.

Note - You should not create a label name that is the same as any other keyword that can be used in filtering because it might create conflicts and unexpected results. You can use the `er_print -describe` command to see the keywords for an experiment.

`er_label` Command Syntax

The syntax of the `er_label` command is:

`er_label -o` *experiment-name* `-n` *label-name* `-t {start|stop}[=`*time-specification*`] [-C` *comment*

The options are defined as follows:

`-o` *experiment-name* is a required option that specifies the name of the experiment that you want to label. Only one experiment name can be specified, and experiment groups are not supported. The `-o` option can appear anywhere on the command line.

`-n` *label-name* is a required option that specifies the label name.

The label-name can be any length, but it must be alphanumeric beginning with a letter and have no embedded spaces even if quotes are used around the string. If the *label-name* exists, the new criteria will be added to it; if it did not exist, it will be created. A single `-n` argument is required, but may appear anywhere on the command line. Label names are case insensitive. Label names must not conflict with other names that can appear in filters, including properties in experiments or names of memory-objects or index-objects. Properties from loaded experiments are listed with the `er_print describe` command. Memory-objects are listed with the `er_print mobj_list` command. Index-objects are listed with the `er_print indxobj_list` command.

`-C` *comment* is an optional comment about the label. You can use multiple `-C` options for a single label, and the comments will be concatenated with a semi-colon and a space between them when the label is displayed. You can use multiple comments, for example, to provide information about each time interval in the label.

`-t start|stop =`*time-specification* is a specification of the start or stop point used to define a time range within the experiment. If `=`*time-specification* is omitted, a marker for current time is created.

The *time-specification* can be specified in one of the following forms:

hh:mm:ss.uuu

Specifies the time relative to the beginning of the experiment where the start or stop marker should be placed. You must specify at least seconds, and can optionally specify hours, minutes, and subseconds.

The time values you specify are interpreted as follows:

nn	If you specify an integer (without colons), it is interpreted as seconds. If the value is greater than 60 the seconds are converted to mm:ss in the label. For example, `-t start=120` places a start marker at 02:00 after the beginning of the experiment.
nn.nn	If you include a decimal of any precision, it is interpreted as a fraction of a second and saved to nanosecond precision. For example, `-t start=120.3` places a start maker at 02:00.300 or 2 minutes and 300 nanoseconds after the beginning of the experiment.
nn:nn	If you specify the time using nn:nn format, it is interpreted as mm:ss, and if the value of mm is greater than 60, the time is converted to hh:mm:ss. The number you specify for ss must be between 0 and 59 or an error occurs. For example, `-t start=90:30` places a start maker at 01:30:30 or 1 hour, 30 minutes, 30 seconds after the beginning of the experiment.
nn:nn:nn	If you specify the time using nn:nn:nn format, it is interpreted as hh:mm:ss. The numbers you specify

for minutes and seconds must be between 0 and 59 or an error occurs. For example, `-t stop=01:45:10` places a stop maker at 1 hour, 45 minutes and 10 seconds after the beginning of the experiment.

`@` Specifies the current time to place a marker in the experiment at the moment when the `er_label` command is executed. The current time is set once in a single invocation of the command, so any additional markers that use the `@` are set relative to that original timestamp value.

`@+`*offset* Specifies a time after the current timestamp, where *offset* is a time that uses the same *hh:mm:ss.uuu* rules described above. This time format places a marker at the specified time after the original timestamp. For example, `-t stop=@+180` places a stop marker at 3 minutes after the current time.

`@-`*offset* Specifies a time before the current timestamp, where *offset* is a time that uses the same *hh:mm:ss.uuu* rules described above. This time format places a marker at the specified time before the original timestamp. For example, `-t start=@-20:00` places a start marker at 20 minutes before the current time. If the experiment has not been running for at least 20 minutes, the marker is ignored.

You can use multiple `-t` specifications in a single `er_label` command, or multiple `-t` specifications in separate commands for the same label name, but they should occur in pairs of `-t start` and `-t stop` markers.

If the `-t start` or `-t stop` option is not followed by any time specification, `=@` is assumed for the specification. You must include a time specification for one of the markers.

For more information, see `er_label(1)`.

`er_label` Examples

EXAMPLE 20 Defining a label with time markers relative to the beginning of the experiment

To define a label named `snap` in the experiment `test.1.er` that covers the part of a run from 15 seconds after the start of the experiment for a duration of 10 minutes, use the following command:

```
% er_label -o test.1.er -n snap -t start=15 -t stop=10:15
```

Alternatively, you can specify the markers for the interval in separate commands:

```
% er_label -o test.1.er -n snap -t start=15
% er_label -o test.1.er -n snap -t stop=10:15
```

EXAMPLE 21 Defining a label with time markers relative to the current time

To define a label named `last5mins` in the experiment `test.1.er` that covers the part of a run from 5 minutes ago to the current time:

```
% er_label -o test.1.er -n last5mins -t start=@-05:00 -t stop
```

Using `er_label` in Scripts

One use of `er_label` is to support profiling a server program that is being driven by a client as an independent process or processes. In this usage model, you start the server with the `collect` command to start creating an experiment on the server. Once the server is started and ready to accept requests from a client, you can run a client script that makes requests to drive the server and runs `er_label` to label the portions of the experiment where the client requests occur.

The following sample client script produces a time label in a `test.1.er` experiment for each request run against the server. Each of the five labels created marks off the time spent processing the named request.

```
for REQ in req1 req2 req3 req4 req5
          do

          echo "========================================================="
          echo " $REQ started at `date`"

          er_label -o test.1.er -n $REQ -t start=@
          run_request $REQ
          er_label -o test.1.er -n $REQ -t stop=@
          done
```

The following sample script shows an alternative usage that produces a single label named `all`, which includes all the requests.

```
for REQ in req1 req2 req3 req4 req5
          do

          echo "========================================================="
          echo " $REQ started at `date`"
```

```
er_label -o test.1.er -n all -t start=@
run_request $REQ
er_label -o test.1.er -n all -t stop
done
```

Note that no time specification follows `-t stop` in the second invocation of `er_label`, so it defaults to `stop=@`.

You can create more complex scripts, and run multiple scripts simultaneously on the same node or on different nodes. If the experiment is located in shared directory accessible by all the nodes, the scripts can mark intervals in the same experiment. The labels in each script can be the same or different.

Other Utilities

Some other utilities generally are not needed in normal circumstances. They are documented here for completeness, with a description of the circumstances in which it might be necessary to use them.

`er_archive` Utility

The syntax of the `er_archive` command is as follows.

```
er_archive  [ -nqF ] [-[d|r] path] [-s option [-m regexp ] ]
     experiment
```

```
er_archive -V
```

`er_archive` runs automatically when an experiment completes normally (unless it was run with archiving turned off). It reads the list of shared objects referenced in the experiment, and copies all shared objects referenced in an experiment into the directory *archives* in the founder experiment. The copies are stored with mangled names so that the founder experiment and its sub-experiments may have different versions of objects with the same name. For Java experiments, all .jar files referenced are also copied into the experiment. (`er_archive` no longer generates *.archive* files.) If the target program terminates abnormally, `er_archive` might not run; In that case, it should be run manually.

If the user wishes to examine the experiment on a different machine from the one on which it was recorded, `er_archive` must either have been run when the experiment completed, or must be manually run on the experiment on the machine on which the data was recorded, in order to get the correct versions of all shared objects.

If the shared object cannot be found, or if it has a timestamp differing from that recorded in the experiment, or if `er_archive` is run on a different machine from that on which the experiment was recorded, the objects are not copied. If `er_archive` was run manually (without the `-q` flag), a warning is written to `stderr`. When an experiment referencing such a shared object is read by `er_print` or Analyzer a warning is also generated.

`er_archive` can also archive sources (including any necessary object files with symbol tables needed) by specifying an `-s` argument when run manually. Archiving of sources can specified to be done automatically when the experiment completes by setting the environment variable `SP_ARCHIVE_ARGS`. That environment variable may contain `-s` and `-m` arguments, as pairs of argument and options separated by one or more blanks. If more than one `-s` argument appears on the command line, the last one prevails. If `-s` is both passed on the command line, and set by the environment variable, the option from the environment variable prevails.

For more information, see `er_archive`(1).

The following sections describe the options accepted by the `er_archive` utility.

–n

Archive the named experiment only, not any of its descendants.

–q

Do not write any warnings to `stderr`. Warnings are incorporated into the archive file, and shown in Performance Analyzer or output from the `er_print` utility.

–F

Force writing or rewriting of archive files. This argument can be used to run `er_archive` by hand, to rewrite files that had warnings.

-d *path*

Specify the absolute location of a common archive.

`-r` *path*

Specify the relative location of a common archive.

`–s` *option*

Specify archiving of source files. The allowed values of *option* are:

`no`	Do not archive any source files
`all`	Archive all source, object, and `.anc` files which can be found.
`used[src]`	Archive source, object and `.anc` files for functions against which data was recorded in the experiment, and which can be found.

If more than one `-s` argument is given on the command line, or specified in the environment variable, the specified option for all must be the same. If not, `er_archive` will exit with an error.

`–m` *regex*

Archive only those source, object, and `.anc` files as specified by the `-s` flag, and whose full pathname, as recorded in the executable or shared object, matches the given *regex*. For more information on regex, see the `regex`(5) man page.

Multiple `-m` arguments can be supplied on the command line or in the environment variable. A source file will be archived if it matches the expression from any of them.

`–V`

Write version number information for the `er_archive` utility and exit.

`er_export` Utility

The syntax of the `er_export` command is as follows.

`er_export [-V]` *experiment*

The `er_export` utility converts the raw data in an experiment into ASCII text. The format and the content of the file are subject to change, and should not be relied on for any use. This utility is intended to be used only when Performance Analyzer cannot read an experiment. The output enables the tool developers to understand the raw data and analyze the failure. The –`V` option prints version number information. For more information, see `er_export`(1).

`er_html` Utility

The syntax of the `er_html` command is as follows:

```
er_html [-AO] [-c path] [-cc compiler_commentary_class] [-ct] [-h]
      [-im metric_list] [-l limit] [-n column_names] [-o|-O directory]
      [-q] [-tp percent] [-v] [-V] experiment-list
```

The `er_html` utility exports one or more of your experiments or experiment groups to a browsable HTML format. You can choose which metrics are displayed and how they're reported, or `er_html` can choose the metrics automatically.

This utility enables you to remotely analyze your application, share the experiment results with others for reviewing, or archive the performance of the application before some modifications are made. For more information on how to use `er_html` and what all the options mean, see the `er_html`(1) man page.

♦ ♦ ♦ C H A P T E R 9

Kernel Profiling

This chapter describes how you can use the Oracle Developer Studio performance tools to profile the kernel while Oracle Solaris is running a load. Kernel profiling is available if you are running Oracle Developer Studio software on Oracle Solaris 10 or Oracle Solaris 11. Kernel profiling is *not* available on Linux systems.

This chapter covers the following topics:

Kernel Experiments

You can record kernel profiles by using Performance Analyzer or using the `er_kernel` utility. When you profile the kernel in Performance Analyzer, you are also running the `er_kernel` utility in the background.

The `er_kernel` utility uses DTrace, a comprehensive dynamic tracing facility that is built into the Oracle Solaris operating system.

The `er_kernel` utility captures kernel profile data and records the data as a Performance Analyzer experiment in a format similar to a user experiment recorded with `collect`. The experiment can be processed by the `er_print` utility or Performance Analyzer. A kernel experiment can show function data, caller-callee data, instruction-level data, and a timeline, but not source-line data because most Oracle Solaris modules do not contain line-number tables.

Setting Up Your System for Kernel Profiling

Before you can use the `er_kernel` utility for kernel profiling, you need to set up access to DTrace.

Normally, DTrace is restricted to user `root`. To run `er_kernel` utility as a user other than `root`, you must have specific privileges assigned, and be a member of group `sys`. To assign the necessary privileges, edit the line for your username as follows in the file `/etc/user_attr`:

```
username::::defaultpriv=basic,dtrace_kernel,dtrace_proc
```

To add yourself to the group `sys`, add your user name to the `sys` line in the file `/etc/group`.

Running the `er_kernel` Utility

You can run the `er_kernel` utility to profile only the kernel or both the kernel and the load you are running. For a complete description, see the `er_kernel(1)` man page.

To display a usage message, run the `er_kernel` command without arguments.

The `er_kernel` option `-p on` is used by default, so you do not need to explicitly specify it.

You can replace the `-p on` argument to the `er_kernel` utility with `-p high` for high-resolution profiling or `-p low` for low-resolution profiling. If you expect the run of the load to take 2 to 20 minutes, the default clock profiling is appropriate. If you expect the run to take less than 2 minutes, use `-p high`; if you expect the run to take longer than 20 minutes, use `-p low`.

You can add a `-t` *duration* argument, which will cause the `er_kernel` utility to terminate itself according to the time specified by *duration*.

The `-t` *duration* can be specified as a single number, with an optional `m` or `s` suffix, to indicate the time in minutes or seconds at which the experiment should be terminated. By default, the duration is in seconds. The *duration* can also be specified as two such numbers separated by a hyphen, which causes data collection to pause until the first time elapses, and at that time data collection begins. When the second time is reached, data collection terminates. If the second number is a zero, data will be collected after the initial pause until the end of the program's run. Even if the experiment is terminated, the target process is allowed to run to completion.

If no time duration or interval is specified, `er_kernel` will run until terminated. You can terminate it by pressing Ctrl-C (`SIGINT`), or by using the `kill` command and sending `SIGINT`, `SIGQUIT`, or `SIGTERM` to the `er_kernel` process. The `er_kernel` process terminates the experiment and runs `er_archive` (unless `-A off` is specified) when any of those signals is sent to the process. The `er_archive` utility reads the list of shared objects referenced in the experiment, and constructs an archive file for each object.

The `-x` option can be used to exclude profile events from idle CPUs and is set to `on` by default so the events are not recorded. You can set `-x off` to record profile events from idle CPUs so all CPU time is accounted for completely.

You can add the `-v` argument if you want more information about the run printed to the screen. The `-n` argument lets you see a preview of the experiment that would be recorded without actually recording anything.

By default, the experiment generated by the `er_kernel` utility is named `ktest.1.er`; the number is incremented for successive runs. You can rename the experiment with the `-o` *experiment-name* option. Alternatively, you can use the `-O` *file* option to append the output from `er_kernel` itself to the named file, but the output from the spawned load won't be redirected. For more information on output options, see the `er_kernel(1)` man page.

▼ To Profile the Kernel with `er_kernel`

1. **Collect the experiment by typing:**

   ```
   % er_kernel -p on
   ```

2. **Run the load in a separate shell.**

3. **When the load completes, terminate the `er_kernel` utility by typing Ctrl-C.**

4. **Load the resulting experiment, named `ktest.1.er` by default, into Performance Analyzer or the `er_print` utility.**

   Kernel clock profiling produces two metrics: KCPU Cycles (metric name `kcycles`), for clock profile events recorded in the kernel founder experiment, and KUCPU Cycles (metric name `kucycles`) for clock profile events recorded in user process subexperiments, when the CPU is in user-mode.

   In Performance Analyzer, the metrics are shown for kernel functions in the Functions view, for callers and callees in the Callers-Callees view, and for instructions in the Disassembly view. The Source view does not show data because kernel modules as shipped do not usually contain file and line symbol table information (stabs).

▼ To Profile Under Load with `er_kernel`

If you have a single command, either a program or a script, that you want to use as a load:

1. **Collect the experiment by typing:**

   ```
   % er_kernel -p on load
   ```

   If *load* is a script, it should wait for any commands it spawns to terminate before exiting, or the experiment might be terminated prematurely.

   The `er_kernel` utility forks a child process and pauses for a quiet period. The child process then runs the specified load. When the load terminates, the `er_kernel` utility pauses again for a quiet period and then exits.

   You can specify the duration of the quiet period in seconds with the `-q` argument to the `er_kernel` command.

2. **Analyze the experiment by typing:**

   ```
   % analyzer ktest.1.er
   ```

   The experiment shows the behavior of the Oracle Solaris kernel during the running of the load, and during the quiet periods before and after. See "Analyzing a Kernel Profile" on page 269 for more information about what you can see in a kernel profile.

Profiling the Kernel for Hardware Counter Overflows

The `er_kernel` utility can collect hardware counter overflow profiles for the kernel using the DTrace `cpc` provider, which is available only on systems running Oracle Solaris 11.

You can perform hardware counter overflow profiling of the kernel with the `-h` option for the `er_kernel` command as you do with the `collect` command. An important difference is that the `collect` command will adjust counter overflow values to match approximately corresponding clock-profile rates. In contrast, `er_kernel` chooses crude, static overflow values that might not be appropriate, especially in the case of raw counter names. The resulting data collection rate might b too low (resulting in noisy data or too high (resulting in distortion of the performance behavior being measured). It is recommended to use aliased name and/or confirm that changing the counter overflow values by a factor of ten does not materially change the performance behaviors you observe.

As with the `collect` command, if no explicit `-p off` argument is given, clock-based profiling is turned on by default. If `-h high` or `-h low` is specified requesting the default counter set for that chip at high- or low-frequency, the default clock-profiling will also be set to high or low; an explicit `-p` argument will be respected.

The `er_kernel -h` command collects hardware-counter overflow profiles using the DTrace cpc provider. Hardware-counter profiling is not available on systems prior to Oracle Solaris 11. If the overflow mechanism on the chip allows the kernel to tell which counter overflowed, as many counters as the chip provides may be used; otherwise, only one counter may be specified.

Dataspace profiling is supported on SPARC systems running DTrace version 1.8 or later, only for precise counters. If requested on a system where it is not supported, the dataspace flag will be ignored, but the experiment will still be run.

The system hardware-counter mechanism can be used by multiple processes for user profiling, but can not be used for kernel profiling if any user process, or `cputrack`, or another `er_kernel` is using the mechanism. In that case, `er_kernel` will report "HW counters are temporarily unavailable; they may be in use for system profiling."

To display hardware counters on a machine whose processor supports hardware counter overflow profiling, run the `er_kernel –h` command with no additional arguments.

If the overflow mechanism on the chip allows the kernel to tell which counter overflowed, you can profile as many counters as the chip provides; otherwise, you can only specify one counter. The `er_kernel -h` output specifies whether you can use more than one counter by displaying a message such as "specify HW counter profiling for up to 4 HW counters."

For more information about hardware counter profiling, see “Hardware Counter Profiling Data” on page 28 and “Hardware Counter Profiling with `collect -h`” on page 69.

Also see the `er_print` man page for more information about hardware counter overflow profiling.

Profiling Kernel and User Processes

The `er_kernel` utility enables you to perform profiling of the kernel and applications. You can use the `-F` option to control whether application processes should be followed and have their data recorded. If you use `er_kernel` to spawn a load and do not specify `-F`, the load will be followed. If you do specify `-F`, the load will be followed if it matched the `-F` expression.

When you use the `-F on` or `-F all` options, `er_kernel` records experiments on all application processes as well as the kernel. User processes that are detected while collecting an `er_kernel` experiment are followed, and a subexperiment is created for each of the followed processes.

Many subexperiments might not be recorded if you run `er_kernel` as a non-root user because unprivileged users usually cannot read anything about another user's processes.

Assuming sufficient privileges, the user process data is recorded only when the process is in user mode, and only the user call stack is recorded. The subexperiments for each followed process contain data for the `kucycles` metric. The subexperiments are named using the format _*process-name*_`PID`_*process-pid*`.1.er`. For example an experiment run on a `sshd` process might be named `_sshd_PID_1264.1.er`.

To follow only some user processes, you can specify a regular expression using `-F =`*regexp* to record experiments on processes whose name or PID matches the regular expression.

For example, `er_kernel -F =synprog` follows processes of a program called `synprog`.

Note that the process name, as read from the `/proc` filesystem by `er_kernel`, is truncated by the OS to a maximum of 15 characters (plus a zero-byte). Patterns should be specified to match a process name so truncated.

See the `regexp`(5) man page for information about regular expressions.

The `-F off` option is set by default so that `er_kernel` does not perform user process profiling.

Note - The `-F` option of `er_kernel` is different from the `-F` option of `collect`. The `collect -F` command is used to follow only processes that are created by the target specified in the command line, while `er_kernel -F` is used to follow any or all processes currently running on the system.

Alternative Method for Profiling Kernel and Load Together

In addition to using `er_kernel -F=`*regexp*, you can profile the kernel and a load together if you run `er_kernel` using a target of `collect` *load* instead of *load*. Only one of the `collect` and `er_kernel` specifications can include hardware counters. If `er_kernel` is using the hardware counters, the `collect` command cannot.

The advantage of this technique is that it collects data on the user processes when they are not running on a CPU, while the user experiment collected by `er_kernel` would only include User CPU Time and System CPU Time. Furthermore, when you use `collect`, you get the data for OpenMP and Java profiling in user mode. With `er_kernel` you can only get machine mode for either, and you will not have any information about HotSpot compilations in a Java experiment.

▼ To Profile the Kernel and Load Together

1. **Collect both a kernel profile and a user profile by typing both the `er_kernel` command and the `collect` command:**

   ```
   % er_kernel collect load
   ```

2. **Analyze the two profiles together by typing:**

   ```
   % analyzer ktest.1.er test.1.er
   ```

   The data displayed by Performance Analyzer shows both the kernel profile from `ktest.1.er` and the user profile from `test.1.er`. The Timeline view enables you to see correlations between the two experiments.

Note - To use a script as the load and separately profile various parts of the script, prepend the `collect` command with the appropriate arguments to the various commands within the script.

Analyzing a Kernel Profile

The kernel founder experiment contains data for the `kcycles` metric. When the CPU is in system-mode the kernel call stacks are recorded. When the CPU is idle a single-frame call stack for the artificial function `<IDLE>` is recorded. When the CPU is in user-mode, a single-frame call stack attributed to the artificial function <*process-name*_`PID`_*process-pid*> is recorded. In the kernel experiment, no call stack information on the user processes is recorded.

The artificial function `<INCONSISTENT_PID>` in the kernel founder experiment indicates where DTrace events were delivered with inconsistent process IDs for unknown reasons.

If `-F` is used to specify following user processes, the subexperiments for each followed process will contain data for the `kucycles`metric. User-level call stacks are recorded for all clock profile events where that process was running in user mode.

You can use filters in the Processes view and the Timeline view to filter down to the PIDs you are interested in.

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