NATURAL ENVIRONMENT RESEARCH COUNCIL

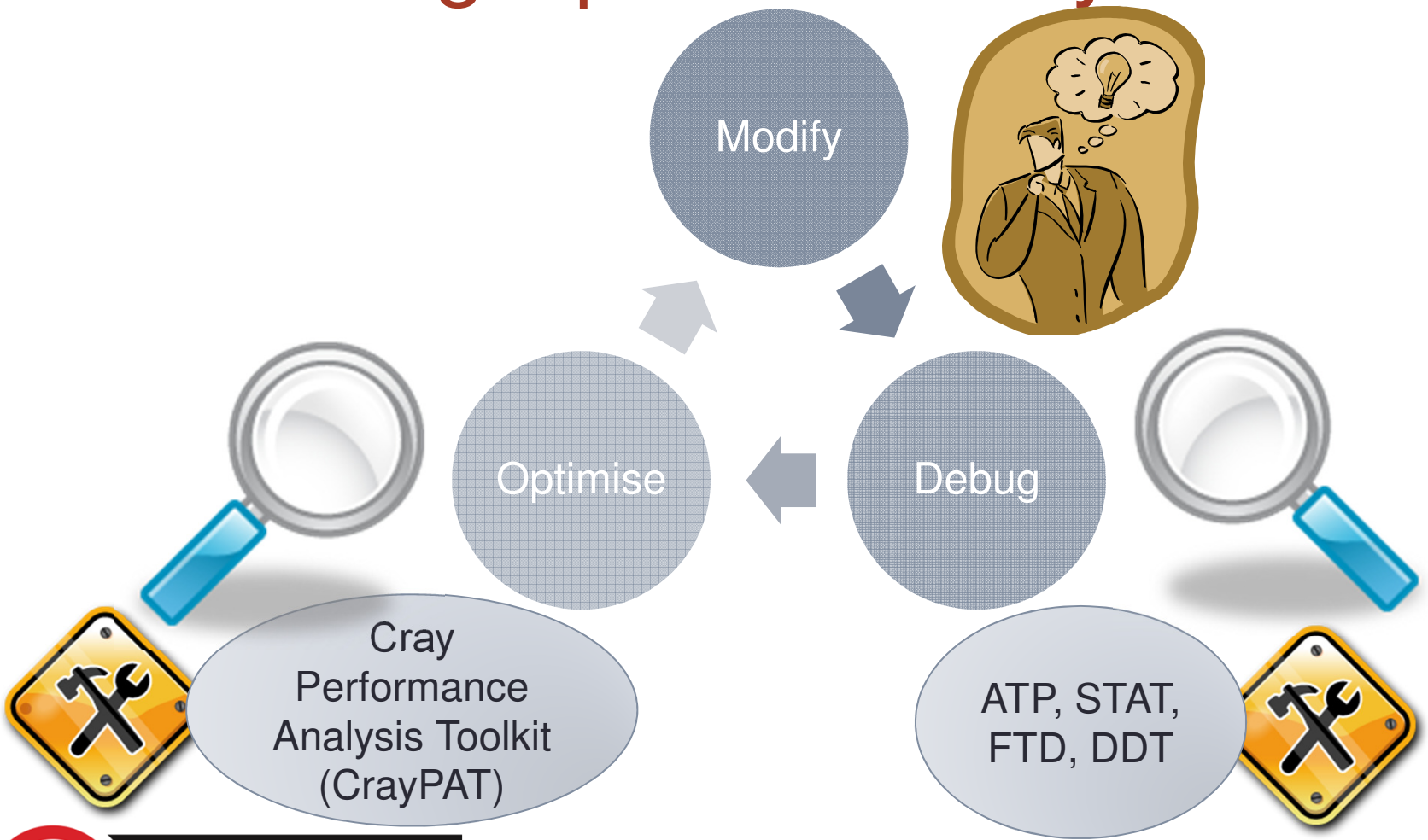
EPSRC

ARCHER Performance and Debugging Tools

Slides contributed by Cray and EPCC

epcc

The Porting/Optimisation Cycle

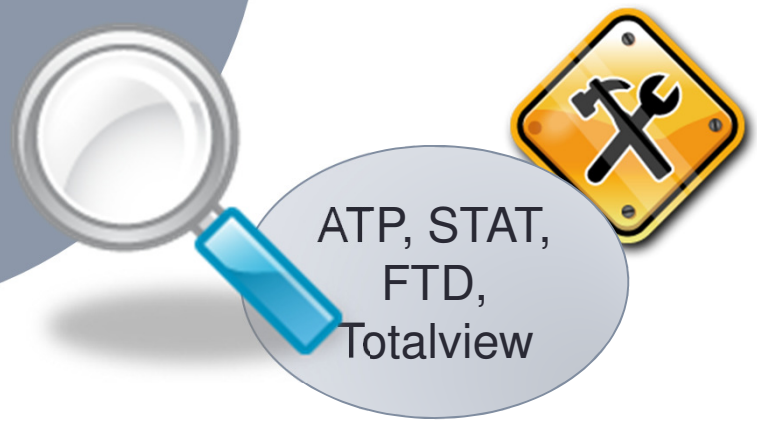


archer

epcc

THE UNIVERSITY OF EDINBURGH

Debug



archer

epcc

THE UNIVERSITY OF EDINBURGH

NATURAL ENVIRONMENT RESEARCH COUNCIL

EPSRC

Abnormal Termination Processing (ATP)

For when things break unexpectedly…
(Collecting back-trace information)

epcc

Debugging in production and scale

- Even with the most rigorous testing, bugs may occur during development or production runs.
  - It can be very difficult to recreate a crash without additional information
  - Even worse, for production codes need to be efficient so usually have debugging disabled
- The failing application may have been using tens of or hundreds of thousands of processes
  - If a crash occurs one, many, or all of the processes might issue a signal.
  - We don't want the core files from every crashed process, they're slow and too big!
  - We don't want a backtrace from every processes, they're difficult to comprehend and analyze.

ATP Description

- Abnormal Termination Processing is a lightweight monitoring framework that detects crashes and provides more analysis
  - Designed to be so light weight it can be used all the time with almost no impact on performance.
  - Almost completely transparent to the user
    - Requires `atp` module loaded during compilation (usually included by default)
    - Output controlled by the `ATP_ENABLED` environment variable (set by system).
  - Tested at scale (tens of thousands of processors)
- ATP rationalizes parallel debug information into three easier to user forms:
  1. A single stack trace of the first failing process to stderr
  2. A visualization of every processes stack trace when it crashed
  3. A selection of representative core files for analysis

Usage

Compilation – environment must have module loaded

```
module load atp
```

Execution (scripts must explicitly set these if not included by default)

```
export ATP_ENABLED=1
ulimit -c unlimited
```

ATP respects `ulimits` on corefiles. So to see corefiles the `ulimit` must change.
On crash ATP will produce a selection of relevant cores files with unique, informative names.

More information (while atp module loaded)

```
man atp
```

NATURAL ENVIRONMENT RESEARCH COUNCIL

EPSRC

Stack Trace Analysis Tool (STAT)

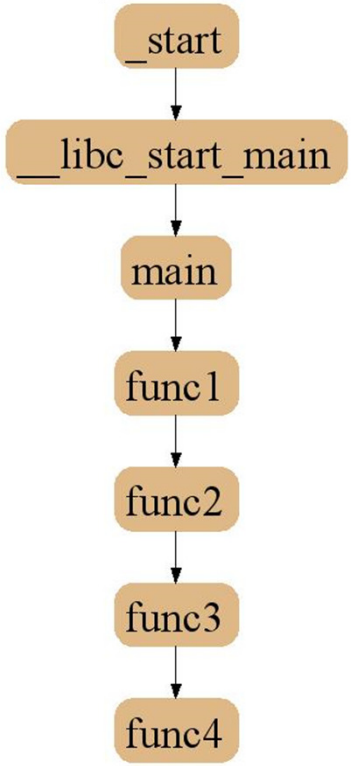
For when nothing appears to be happening…

epcc

THE UNIVERSITY OF EDINBURGH

STAT

- Stack Trace Analysis Tool (STAT) is a cross-platform tool from the University of Wisconsin-Madison.
- ATP is based on the same technology as STAT. Both gather and merge stack traces from a running application's parallel processes.
- It is very useful when application seems to be stuck/hung



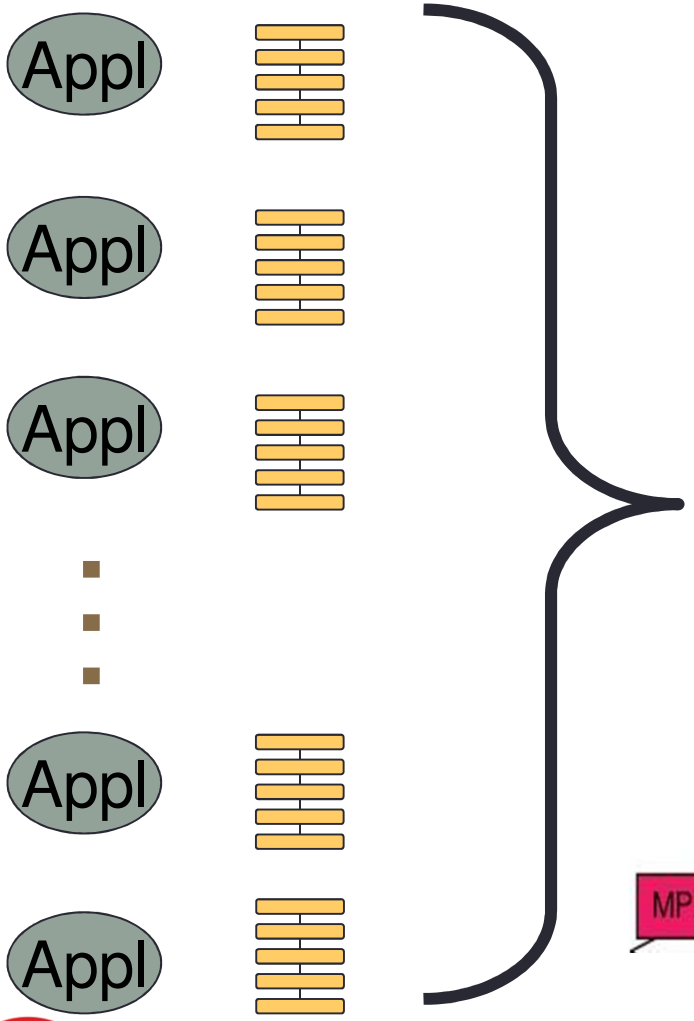
- Full information including use cases is available at http://www.paradyn.org/STAT/STAT.html
- Scales to many thousands of concurrent process, only limited by number file descriptors
- STAT 1.2.1.3 is the default version on Sisu.

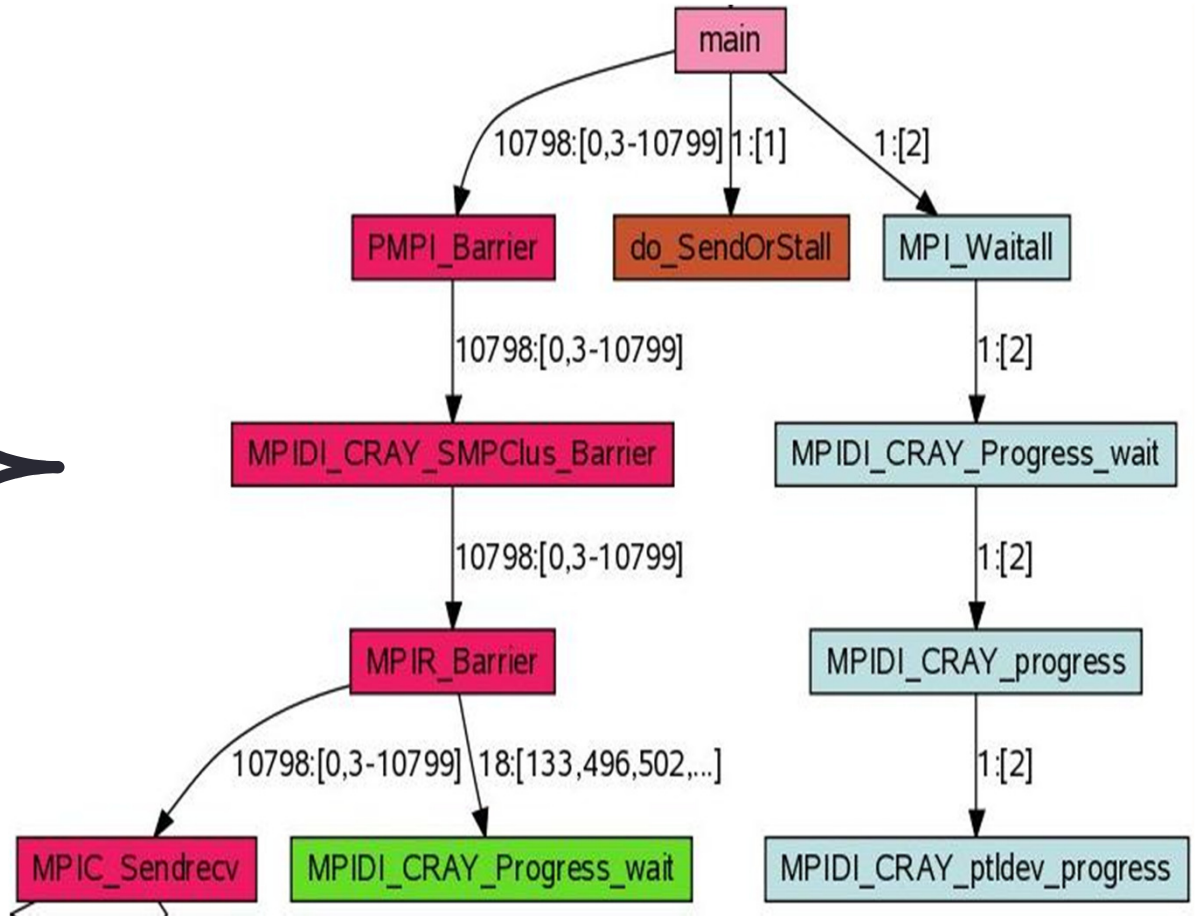
archer

epcc

THE UNIVERSITY OF EDINBURGH

2D-Trace/Space Analysis





archer

epcc

THE UNIVERSITY OF EDINBURGH

Using STAT

Start an interactive job…

```
module load stat

<launch job script> &

# Wait until application hangs:

STAT <pid of aprun>

# Kill job

statview STAT_results/<exe>/<exe>.0000.dot
```

NATURAL ENVIRONMENT RESEARCH COUNCIL

EPSRC

LGDB

Diving in through the command line…

epcc

lgdb - Command line debugging

- LGDB is a line mode parallel debugger for Cray systems
  - Available through `cray-lgdb` module
  - Binaries should be compiled with debugging enabled, e.g. –g. (Or Fast-Track Debugging see later).
  - The recent 2.0 update has introduced new features. All previous syntax is deprecated
- It has many of the features of the standard GDB debugger, but includes extensions for handling parallel processes.

It can launch jobs, or attach to existing jobs

1. To launch a new version of <exe>
   1. Launch an interactive session
   2. Run `lgdb`
   3. Run `launch $pset{nprocs} <exe>`
2. To attach to an existing job
   1. find the `<apid>` using `apstat`.
   2. launch `lgdb`
   3. run `attach $<pset> <apid>` from the `lgdb` shell.

NATURAL ENVIRONMENT RESEARCH COUNCIL

EPSRC

DDT Debugging

Graphical debugging on ARCHER

epcc

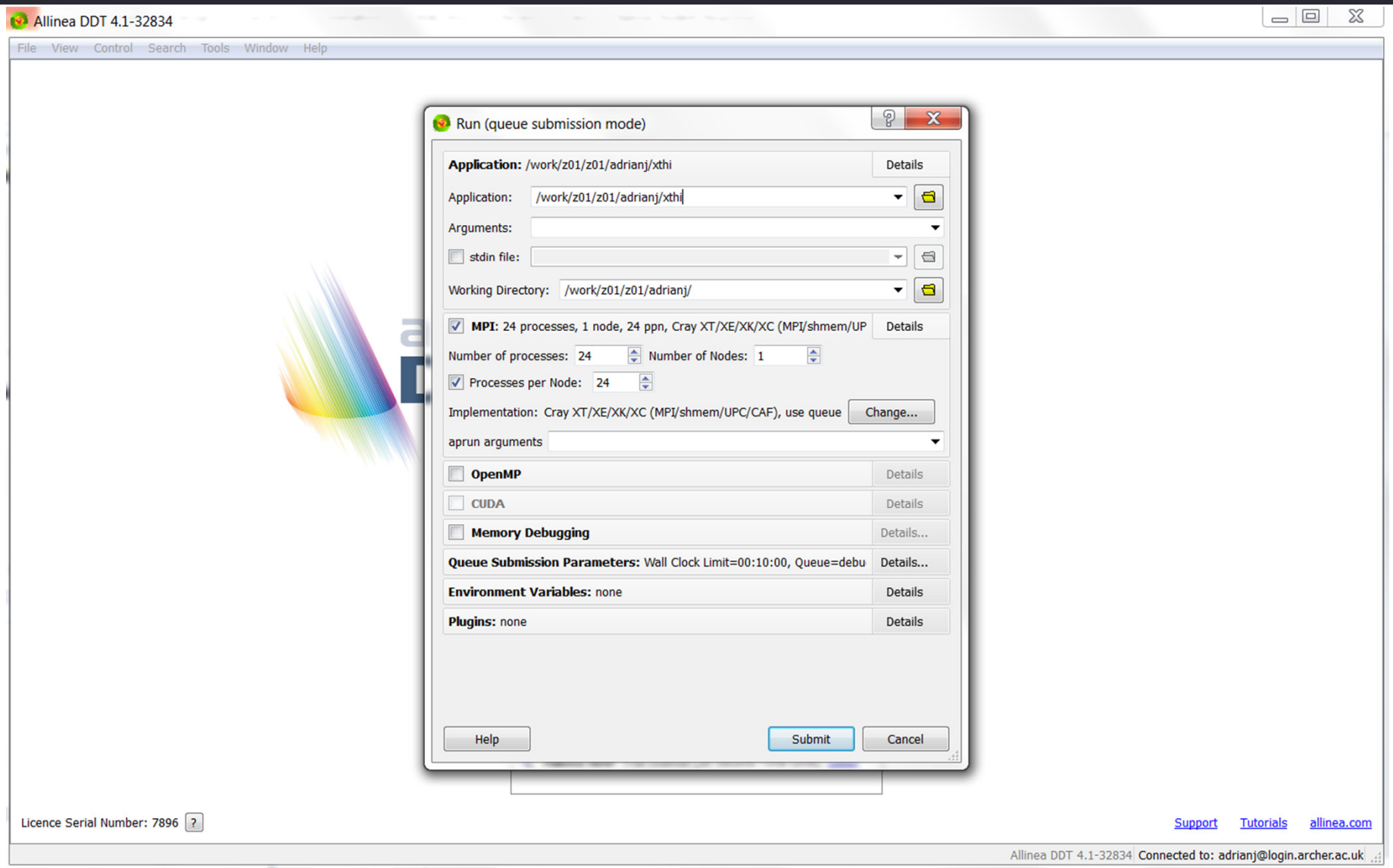
Debugging MPI programs: DDT

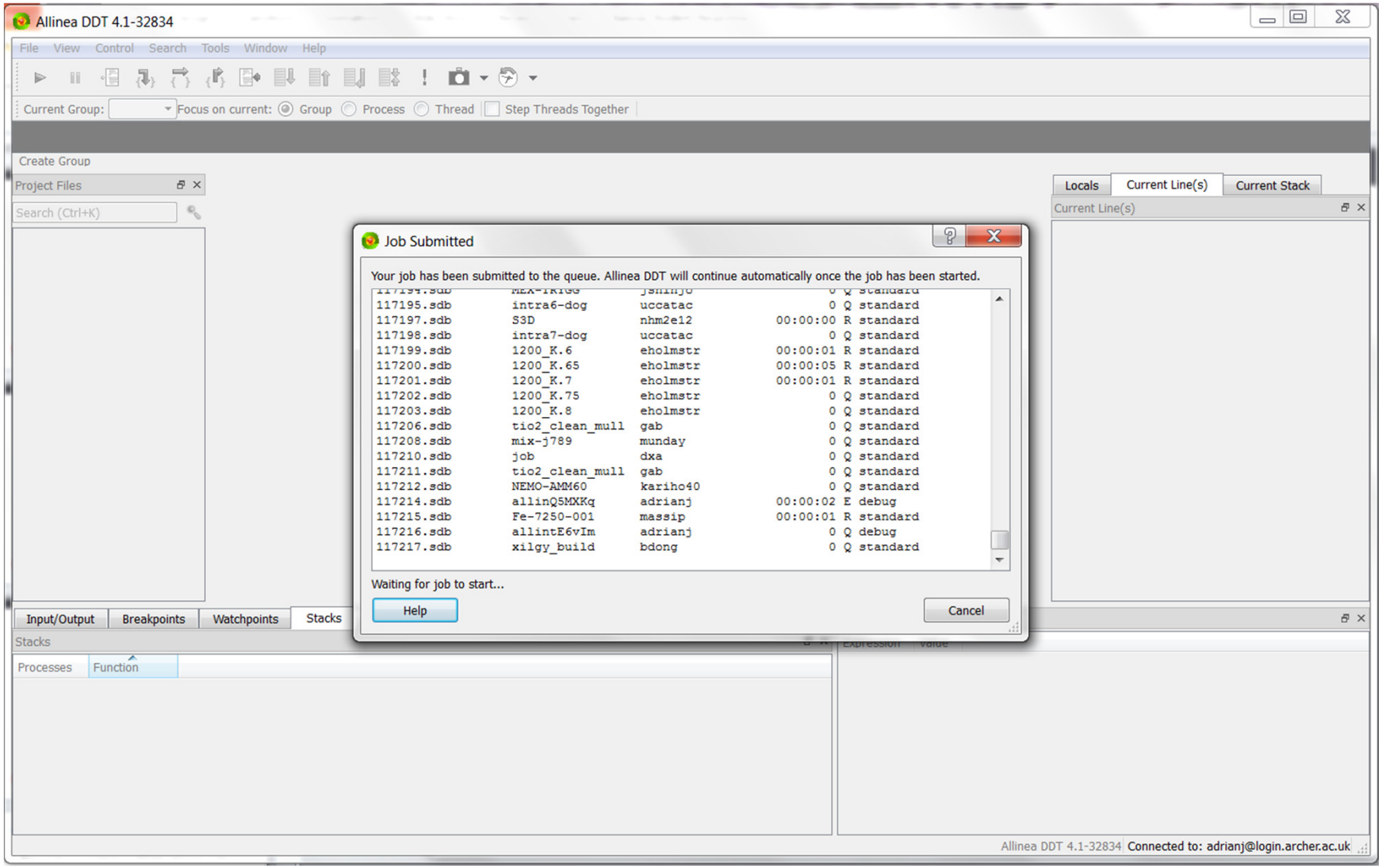
- Allinea DDT installed on ARCHER
- The recommended way to use DDT on ARCHER is to install the free DDT remote client on your workstation or laptop and use this to run DDT on ARCHER.
- The version of the DDT remote client must match the version of DDT installed on ARCHER
  - **currently version 4.2.1**
  - http://www.allinea.com/products/downloads/clients

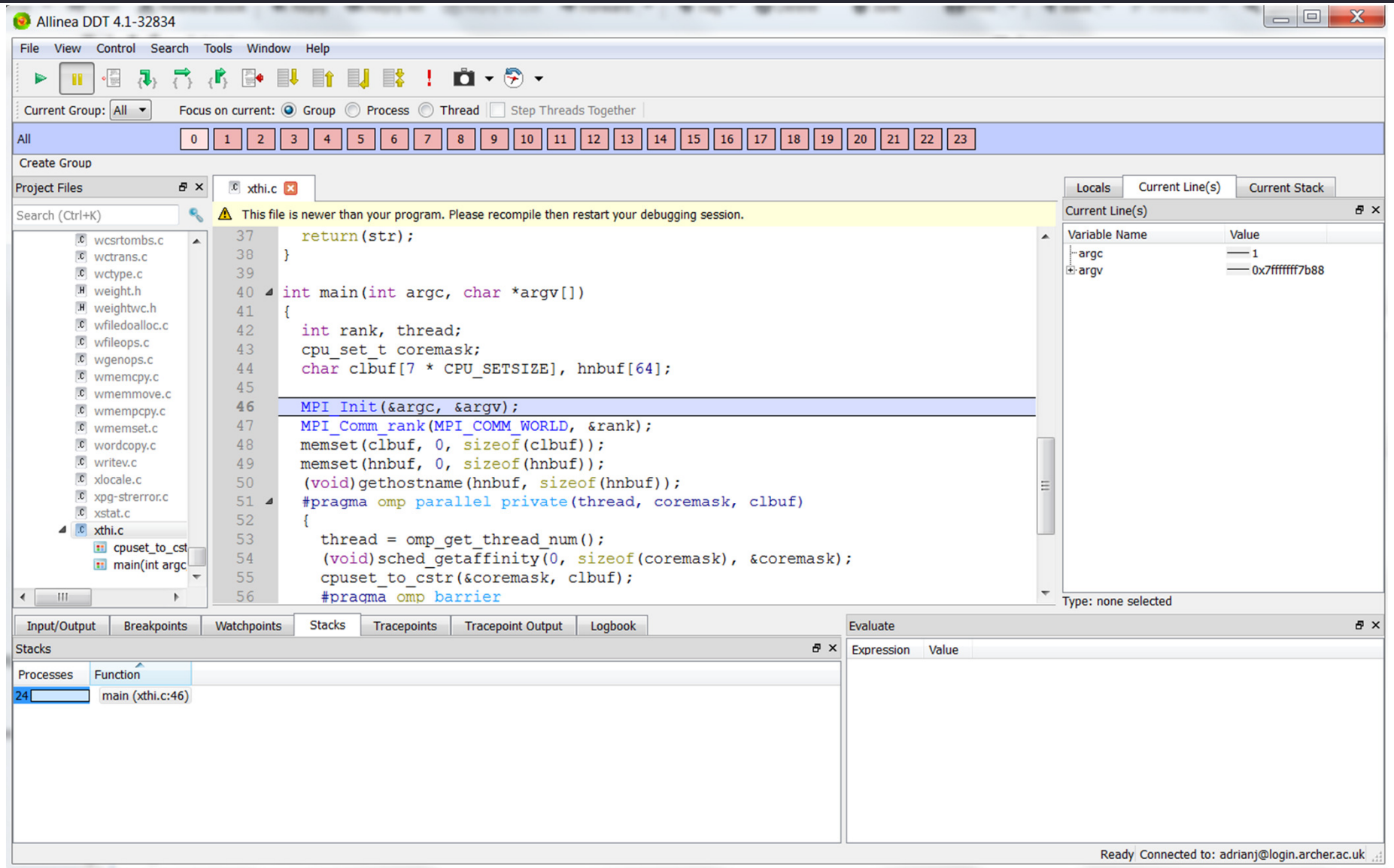
Compiling for debugging

- install the source code on the /work filesystem
- compile the executable into a location on /work to ensure that the running job can access all of the required files.
- Turn off compiler optimisation and turn on debugging
  - -O0 –g


Allinea DDT 4.1-32834
Allinea DDT 4.1-32834
File View Control Search Tools Window Help
allinea DDT
Run
Run and debug a program.
Attach
Attach to an already running program.
Open Core
Open a core file from a previous run.
Manual Launch (Advanced)
Manually launch the backend yourself.
Options
Remote Launch:
adrianj@login.archer.ac.uk
Quit
Available Tools:
Allinea DDT Support Expires 2017-09-15
Allinea MAP Trial Licence (30 Second Time Limit) Sales
Licence Serial Number: 7896
Support Tutorials allinea.com
Allinea DDT 4.1-32834 Connected to: adrianj@login.archer.ac.uk
Allinea DDT 4.1-32834

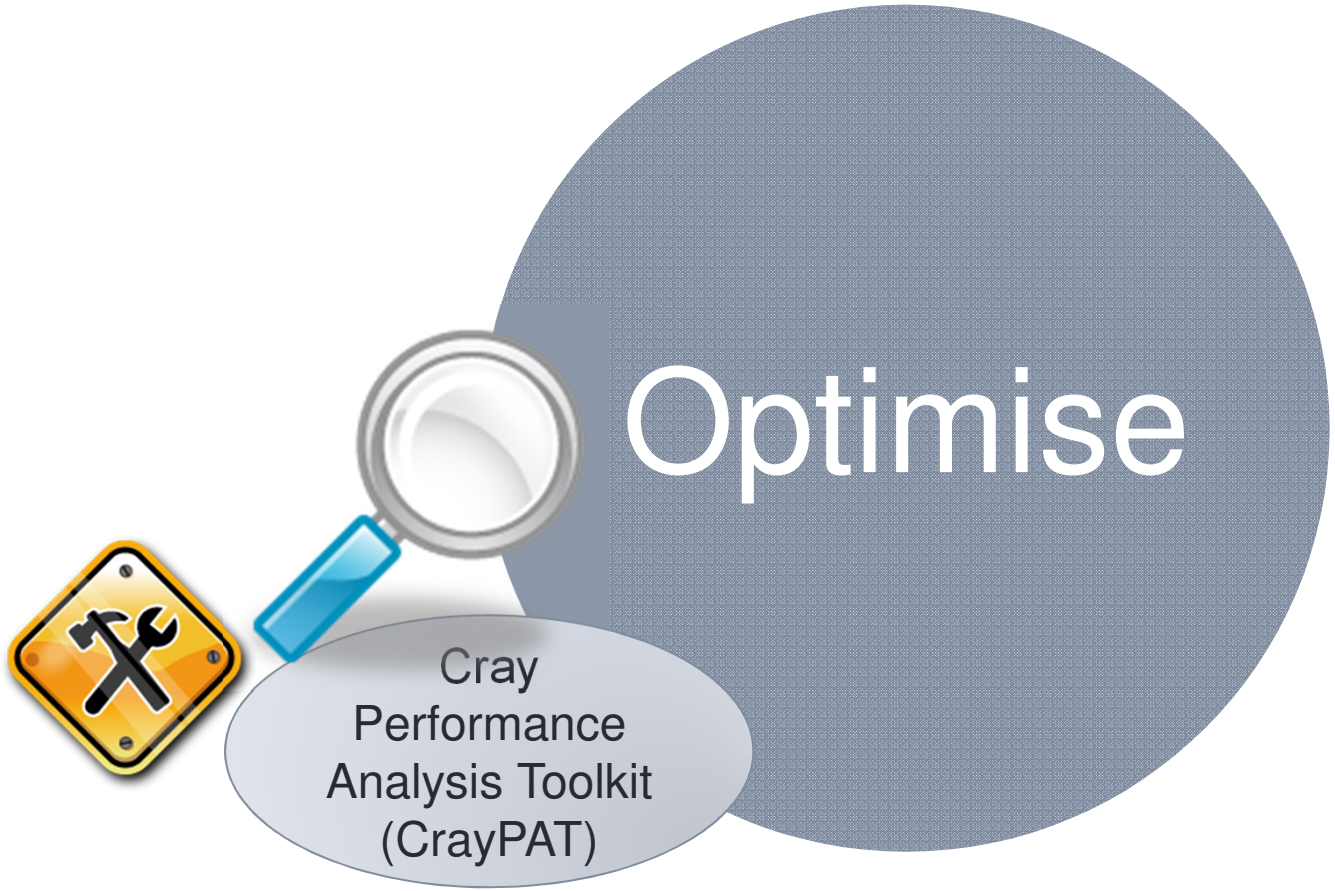

Allinea DDT 4.1-32834
File View Control Search Tools Window Help
Run (queue submission mode)
Application: /work/z01/z01/adrianj/xthi
Details
Application: /work/z01/z01/adrianj/xthi
Arguments:
stdin file:
Working Directory: /work/z01/z01/adrianj/
MPI: 24 processes, 1 node, 24 ppn, Cray XT/XE/XK/XC (MPI/shmem/UP
Details
Number of processes: 24
Number of Nodes: 1
Processes per Node: 24
Implementation: Cray XT/XE/XK/XC (MPI/shmem/UPC/CAF), use queue
Change...
aprun arguments
OpenMP
Details
CUDA
Details
Memory Debugging
Details...
Queue Submission Parameters: Wall Clock Limit=00:10:00, Queue=debu
Details...
Environment Variables: none
Details
Plugins: none
Details
Help
Submit
Cancel
Licence Serial Number: 7896
Support
Tutorials
allinea.com
Allinea DDT 4.1-32834
Connected to: adrianj@login.archer.ac.uk


Allinea DDT 4.1-32834
File View Control Search Tools Window Help
Current Group: Focus on current: Group Process Thread Step Threads Together
Create Group
Project Files
Search (Ctrl+K)
Locals Current Line(s) Current Stack
Current Line(s)
Job Submitted
Your job has been submitted to the queue. Allinea DDT will continue automatically once the job has been started.
117195.sdb intra6-dog uccatac 0 Q standard
117197.sdb S3D nhm2e12 00:00:00 R standard
117198.sdb intra7-dog uccatac 0 Q standard
117199.sdb 1200_K.6 eholmstr 00:00:01 R standard
117200.sdb 1200_K.65 eholmstr 00:00:05 R standard
117201.sdb 1200_K.7 eholmstr 00:00:01 R standard
117202.sdb 1200_K.75 eholmstr 0 Q standard
117203.sdb 1200_K.8 eholmstr 0 Q standard
117206.sdb tio2_clean_mull gab 0 Q standard
117208.sdb mix-j789 munday 0 Q standard
117210.sdb job dxa 0 Q standard
117211.sdb tio2_clean_mull gab 0 Q standard
117212.sdb NEMO-AMM60 kariho40 0 Q standard
117214.sdb allinQ5MXKq adrianj 00:00:02 E debug
117215.sdb Fe-7250-001 massip 00:00:01 R standard
117216.sdb allintE6vIm adrianj 0 Q debug
117217.sdb xilgy_build bdong 0 Q standard
Waiting for job to start...
Help
Cancel
Input/Output Breakpoints Watchpoints Stacks
Stacks
Processes Function
Allinea DDT 4.1-32834 Connected to: adrianj@login.archer.ac.uk


Allinea DDT 4.1-32834
File View Control Search Tools Window Help
Current Group: All
Focus on current: Group Process Thread Step Threads Together
All 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Create Group
Project Files
Search (Ctrl+K)
wcsrtombs.c
wctrans.c
wctype.c
weight.h
weightwc.h
wfiledoalloc.c
wfileops.c
wgenops.c
wmemcpy.c
wmemmove.c
wmempcpy.c
wmemset.c
wordcopy.c
writev.c
xlocale.c
xpg-strerror.c
xstat.c
xthi.c
cpuset_to_cst
main(int argc
xthi.c
This file is newer than your program. Please recompile then restart your debugging session.
37 return(str);
38 }
39
40 int main(int argc, char *argv[])
41 {
42 int rank, thread;
43 cpu_set_t coremask;
44 char clbuf[7 * CPU_SETSIZE], hnbuf[64];
45
46 MPI_Init(&argc, &argv);
47 MPI_Comm_rank(MPI_COMM_WORLD, &rank);
48 memset(clbuf, 0, sizeof(clbuf));
49 memset(hnbuf, 0, sizeof(hnbuf));
50 (void)gethostname(hnbuf, sizeof(hnbuf));
51 #pragma omp parallel private(thread, coremask, clbuf)
52 {
53 thread = omp_get_thread_num();
54 (void)sched_getaffinity(0, sizeof(coremask), &coremask);
55 cpuset_to_cstr(&coremask, clbuf);
56 #pragma omp barrier
Locals Current Line(s) Current Stack
Current Line(s)
Variable Name Value
argc 1
argv 0x7fffffff7b88
Type: none selected
Input/Output Breakpoints Watchpoints Stacks Tracepoints Tracepoint Output Logbook
Stacks
Processes Function
24 main (xthi.c:46)
Evaluate
Expression Value
Ready Connected to: adrianj@login.archer.ac.uk

DDT options

- Play: run processes in current group until they are stopped.
- Pause: pause processes in current group for examination.
- Add Breakpoint: adds a breakpoint at a line of code, or a function, causing processes to pause when they reach it.
- Step Into: step the current process group by a single line or, if the line involves a function call, into the function instead.
- Step Over: steps the current process group by a single line.
- Step Out: will run the current process group to the end of their current function, and return to the calling location.



archer

epcc

THE UNIVERSITY OF EDINBURGH

Sampling

Advantages

- Only need to instrument main routine
- Low Overhead – depends only on sampling frequency
- Smaller volumes of data produced

Disadvantages

- Only statistical averages available
- Limited information from performance counters

Event Tracing

Advantages

- More accurate and more detailed information
- Data collected from every traced function call not statistical averages

Disadvantages

- Increased overheads as number of function calls increases
- Huge volumes of data generated

The best approach is *guided tracing*.

e.g. Only tracing functions that are not small (i.e. very few lines of code) and contribute a lot to application's run time.

APA is an automated way to do this.

Automatic Profile Analysis

A two step process to create a guided event trace binary.

Program Instrumentation - Automatic Profiling Analysis

- **Automatic profiling analysis** (APA)
- Provides simple procedure to instrument and collect performance data as a first step for novice and expert users
- Identifies top time consuming routines
- Automatically creates instrumentation template customized to application for future in-depth measurement and analysis

Steps to Collecting Performance Data

- Access performance tools software

```
% module load perftools
```

- Build application keeping .o files (CCE: `-h keepfiles`)

```
% make clean
% make
```

- Instrument application for automatic profiling analysis
  - You should get an instrumented program `a.out+pat`

```
% pat_build -O apa a.out
```

We are telling `pat_build` that the output of this sample run will be used in an APA run

- Run application to get top time consuming routines
  - You should get a performance file ("`<sdatafile>.xf`") or multiple files in a directory `<sdatadir>`

```
% aprun … a.out+pat  (or qsub <pat script>)
```

Steps to Collecting Performance Data (2)

- Generate text report and an `.apa` instrumentation file

```
% pat_report -o my_sampling_report [<sdatafile>.xf |
   <sdatadir>]
```

- Inspect `.apa` file and sampling report
- Verify if additional instrumentation is needed

Generating Event Traced Profile from APA

- Instrument application for further analysis (a.out+apa)

```
% pat_build -O <apafile>.apa
```

- Run application

```
% aprun … a.out+apa   (or   qsub <apa script>)
```

- Generate text report and visualization file (.ap2)

```
% pat_report -o my_text_report.txt [<datafile>.xf | <datadir>]
```

- View report in text and/or with Cray Apprentice[2]

```
% app2 <datafile>.ap2
```

EPSRC

Analysing Data with `pat_report`

Using pat_report

- Always need to run `pat_report` at least once to perform data conversion
  - Combines information from `xf` output (optimized for writing to disk) and binary with raw performance data to produce `ap2` file (optimized for visualization analysis)
  - Instrumented binary must still exist when data is converted!
  - Resulting `ap2` file is the input for subsequent `pat_report` calls and Apprentice[2]
  - `xf` and instrumented binary files can be removed once `ap2` file is generated.

- Generates a text report of performance results
  - Data laid out in tables
  - Many options for sorting, slicing or dicing data in the tables.
    - `pat_report -O <table option> *.ap2`
    - `pat_report -O help` (list of available profiles)
  - Volume and type of information depends upon sampling vs tracing.

Job Execution Information

```
CrayPat/X:  Version 6.1.2 Revision 11877 (xf 11595)  09/27/13 12:00:25

Number of PEs (MPI ranks):   32

Numbers of PEs per Node:     16  PEs on each of  2  Nodes

Numbers of Threads per PE:    1

Number of Cores per Socket:  12

Execution start time:  Wed Nov 20 15:39:32 2013

System name and speed:  mom2 2701 MHz
```

Sampling Output (Table 2)

```
 Samp%  |  Samp   |  Imb.   |  Imb.   |Group
        |         |  Samp   | Samp%   | Function
        |         |         |         |  Source
        |         |         |         |   Line
        |         |         |         |    PE=HIDE

 100.0% | 7607.1 |     -- |     -- |Total
|-------------------------------------------------------------------------
|  67.6% | 5139.8 |     -- |     -- |USER
||------------------------------------------------------------------------
|  67.5% | 5136.8 |     -- |     -- | cfd_
3        |        |        |        |  training/201312-CSE-EPCC/reggrid/cfd.f
||||----------------------------------------------------------------------
4|||   1.1% |   85.7 |   31.3 |  27.6% |line.202
4|||  25.0% | 1905.1 |  319.9 |  14.8% |line.204
4|||  12.4% |  943.9 |  329.1 |  26.7% |line.206
4|||  23.5% | 1785.5 |  402.5 |  19.0% |line.216
4|||   4.3% |  324.9 |  134.1 |  30.2% |line.218
||||======================================================================
||=======================================================================
|  31.8% | 2421.7 |     -- |     -- |MPI
||------------------------------------------------------------------------
||  13.7% | 1038.5 |  315.5 |  24.1% |MPI_SSEND
||   7.2% |  547.1 | 3554.9 |  89.5% |mpi_recv
||   7.1% |  540.4 | 3559.6 |  89.6% |MPI_WAIT
||   3.8% |  290.8 |  319.2 |  54.0% |mpi_finalize
|==========================================================================
```

pat_report: Flat Profile

```
Table 1:  Profile by Function

 Samp%  |  Samp   |  Imb.   |  Imb.  |Group
        |         |  Samp   | Samp%  | Function
        |         |         |        |  PE=HIDE

 100.0% | 7607.1 |     -- |     -- |Total
|-----------------------------------------------
|  67.6% | 5139.8 |     -- |     -- |USER
||----------------------------------------------
|  67.5% | 5136.8 | 1076.2 |  17.9% | cfd_
||==============================================
|  31.8% | 2421.7 |     -- |     -- |MPI
||----------------------------------------------
||  13.7% | 1038.5 |  315.5 |  24.1% |MPI_SSEND
||   7.2% |  547.1 | 3554.9 |  89.5% |mpi_recv
||   7.1% |  540.4 | 3559.6 |  89.6% |MPI_WAIT
||   3.8% |  290.8 |  319.2 |  54.0% |mpi_finalize
|==============================================
================  Observations and suggestions  ========================

MPI Grid Detection:

    A linear pattern was detected in MPI sent message traffic.
    For table of sent message counts, use -O mpi_dest_counts.
    For table of sent message bytes, use -O mpi_dest_bytes.
=================================================================
```

pat_report: Hardware Performance Counters

```
================================================================
  Total
----------------------------------------------------------------
  PERF_COUNT_HW_CACHE_L1D:ACCESS                    99236829284
  PERF_COUNT_HW_CACHE_L1D:PREFETCH                   1395603690
  PERF_COUNT_HW_CACHE_L1D:MISS                       5235958322
  CPU_CLK_UNHALTED:THREAD_P                        229602167200
  CPU_CLK_UNHALTED:REF_P                             7533538184
  DTLB_LOAD_MISSES:MISS_CAUSES_A_WALK                  29102852
  DTLB_STORE_MISSES:MISS_CAUSES_A_WALK                  6702254
  L2_RQSTS:ALL_DEMAND_DATA_RD                        3448321934
  L2_RQSTS:DEMAND_DATA_RD_HIT                        3019403605
  User time (approx)               76.128 secs   205620987829 cycles
  CPU_CLK                           3.048GHz
  TLB utilization                2956.80 refs/miss     5.775 avg uses
  D1 cache hit,miss ratios         95.1% hits           4.9% misses
  D1 cache utilization (misses)    20.22 refs/miss     2.527 avg hits
  D2 cache hit,miss ratio          91.8% hits           8.2% misses
  D1+D2 cache hit,miss ratio       99.6% hits           0.4% misses
  D1+D2 cache utilization         246.83 refs/miss    30.853 avg hits
  D2 to D1 bandwidth            2764.681MB/sec  220692603786 bytes
```

Some important options to pat_report -O

```
callers                   Profile by Function and Callers
callers+hwpc              Profile by Function and Callers
callers+src               Profile by Function and Callers, with Line Numbers
callers+src+hwpc          Profile by Function and Callers, with Line Numbers
calltree                  Function Calltree View
heap_hiwater              Heap Stats during Main Program
hwpc                      Program HW Performance Counter Data
load_balance_program+hwpc  Load Balance across PEs
load_balance_sm           Load Balance with MPI Sent Message Stats
loop_times                Loop Stats by Function (from -hprofile_generate)
loops                     Loop Stats by Inclusive Time (from -hprofile_generate)
mpi_callers               MPI Message Stats by Caller
profile                   Profile by Function Group and Function
profile+src+hwpc          Profile by Group, Function, and Line
samp_profile              Profile by Function
samp_profile+hwpc         Profile by Function
samp_profile+src          Profile by Group, Function, and Line

For a full list see pat_report -O help
```