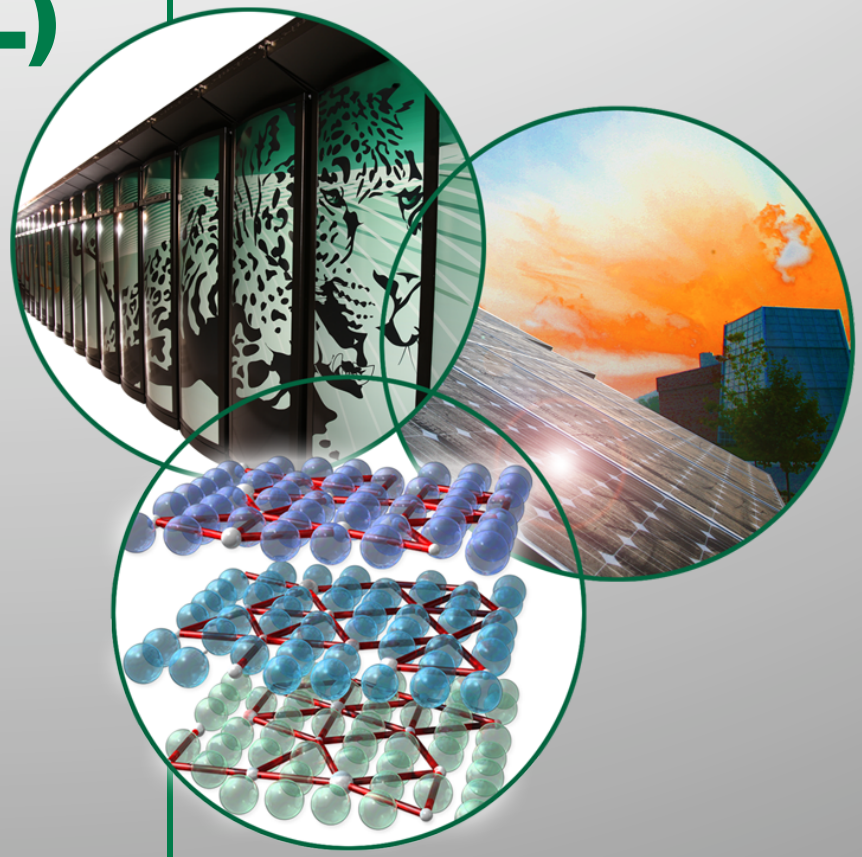
General Purpose Timing Library (GPTL)

A tool for characterizing parallel and serial application performance



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Outline

- Existing tools
- Motivation
- API
- Interface to PAPI
- Auto-profiling
- Usage examples
- Internals
- Future work

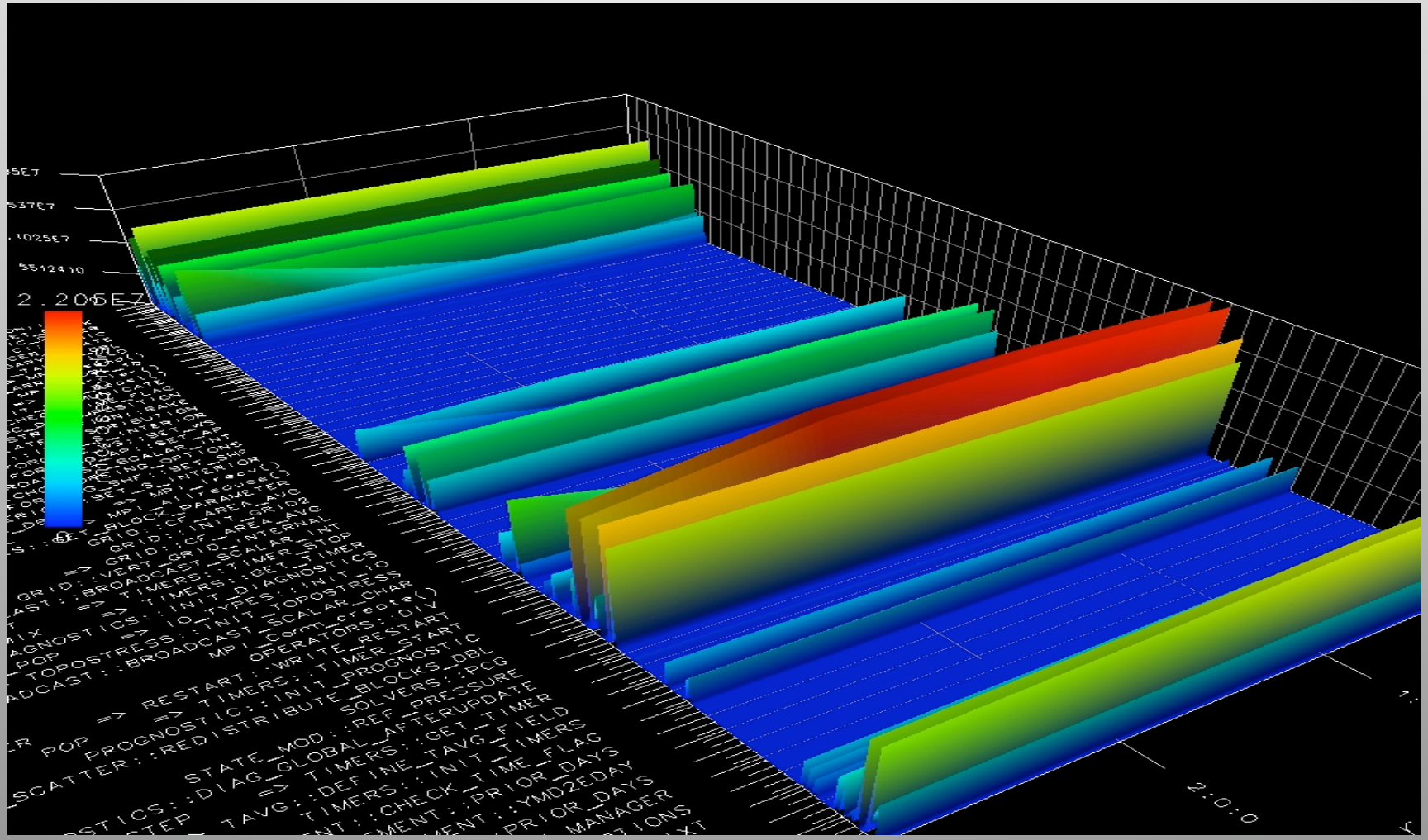
Existing tools

- gprof
- HPCtoolkit
- PAPI
- fpmpi
- Tau
- Vampir

hpcprof

```
1342   0.1%     do j=this_block%jb,this_block%je
1343            do i=this_block%ib,this_block%ie
1344   3.0%        AX(i,j,bid) = A0 (i ,j ,bid)*X(i ,j ,bid) + &
1345                              AN (i ,j ,bid)*X(i ,j+1,bid) + &
1346                              AN (i ,j-1,bid)*X(i ,j-1,bid) + &
1347                              AE (i ,j ,bid)*X(i+1,j ,bid) + &
1348                              AE (i-1,j ,bid)*X(i-1,j ,bid) + &
1349                              ANE(i ,j ,bid)*X(i+1,j+1,bid) + &
1350                              ANE(i ,j-1,bid)*X(i+1,j-1,bid) + &
1351                              ANE(i-1,j ,bid)*X(i-1,j+1,bid) + &
1352                              ANE(i-1,j-1,bid)*X(i-1,j-1,bid)
```

TAU



Why use GPTL?

- Easy to use
  - All that's required to auto-instrument a code is to add a compiler flag and 3 GPTL function calls.
- Auto-instrumentation provides automatic call-tree generation
- Thread-safe, and provides info on multiple threads
- Assesses it's own memory and wallclock overhead
- OK to mix manual and auto-instrumentation
- Utilities provided to summarize results across MPI tasks
- Free, already exists as a module on ORNL XT4/XT5

Motivation

- Needed something to simplify, for an arbitrary number of regions to be timed:

```
time = 0;
for (i = 0; i < 10; i++) {
  gettimeofday (tp1,0);
  compute ();
  gettimeofday (tp2,0);
  delta = tp2.tv_sec - tp1.tv_sec +
          1.e6*(tp2.tv_usec - tp1.tv_usec);
  time += delta;
}
printf ("compute region took %g seconds\n", time);
```

Motivation (cont'd)

- **Solution:**

```
GPTLstart ("total");
for (i = 0; i < 10; i++) {
  GPTLstart ("compute");
  compute ();
  GPTLstop ("compute");
  ...
}
GPTLstop ("total");
GPTLpr_file ("timing.results");
```

Results

- Output file timing.results will contain:

```
                          Called   Wallclock
total                          1       3.983
  compute                     10       3.877
```

Fortran Interface

- Identical to C except for case-insensitivity

```
include 'gptl.inc'
ret = gptlstart ("total")
do i=0,9
  ret = gptlstart ("compute")
  call compute ()
  ret = gptlstop ("compute")
  ...
end do
ret = gptlstop ("total")
ret = gptlpr_file ("timing.results")
```

API

```
#include <gptl.h>

...

GPTLsetoption (GPTLoverhead, 0); // Don't print overhead

GPTLsetoption (PAPI_FP_OPS, 1);  // Enable a PAPI counter

GPTLsetutr (GPTLnanotime);       // Better wallclock timer

...

GPTLinitialize ();       // Once per process

GPTLstart ("total");     // Start a timer

GPTLstart ("compute");   // Start another timer

compute ();              // Do work

GPTLstop ("compute");    // Stop a timer

...

GPTLstop ("total");      // Stop a timer

GPTLpr (iam);            // Print results

GPTLpr_file (filename); // Print results
```

Available underlying timing routines

```
GPTLsetutr (GPTLgettimeofday);     // default
GPTLsetutr (GPTLnanotime);         // x86
GPTLsetutr (GPTLmpiwtime);         // MPI_Wtime
GPTLsetutr (GPTLclockgettime);     // clock_gettime
GPTLsetutr (GPTLpapitime);         // PAPI_get_real_usec
```

- Fastest and most accurate is GPTLnanotime
- Most ubiquitous is GPTLgettimeofday

Set options via Fortran namelist

- Instead of coding multiple lines of gptlsetoption() and gptlsetutr() calls, then recompiling for each configuration:

```
call gptlprocess_namelist ('my_namelist', unitno, ret)
```

- Example contents of my_namelist:

```
&gptlnl
 utr = 'nanotime'
 eventlist = 'GPTL_CI','PAPI_FP_OPS'
 print_method = 'full_tree'
/
```

Threaded example

- **Works on threaded codes too:**

```
ret = gptlstart ('total')           ! Start a timer

!$OMP PARALLEL DO PRIVATE (iter)    ! Threaded loop

  do iter=1,nompiter

    ret = gptlstart ('A')           ! Start a timer

    ret = gptlstart ('B')           ! Start another timer

    ret = gptlstart ('C')

    call sleep (iter)               ! Sleep for "iter" seconds

    ret = gptlstop ('C')            ! Stop a timer

    ret = gptlstart ('CC')

    ret = gptlstop ('CC')

    ret = gptlstop ('A')

    ret = gptlstop ('B')

  end do

  ret = gptlstop ('total')
```

Threaded results

```
Stats for thread 0:

             Called Recurse Wallclock max       min
  total           1    -       2.000     2.000     2.000
    A             1    -       1.000     1.000     1.000
      B           1    -       1.000     1.000     1.000
        C         1    -       1.000     1.000     1.000
        CC        1    -       0.000     0.000     0.000
Total calls           = 5
Total recursive calls = 0


Stats for thread 1:
        Called Recurse Wallclock max       min
  A             1    -       2.000     2.000     2.000
    B           1    -       2.000     2.000     2.000
      C         1    -       2.000     2.000     2.000
      CC        1    -       0.000     0.000     0.000
Total calls           = 4
Total recursive calls = 0
```

PAPI details handled by GPTL

- This call:

```
GPTLsetoption (PAPI_FP_OPS, 1);
```

- Implies:

```
PAPI_library_init (PAPI_VER_CURRENT));
PAPI_thread_init ((unsigned long (*)(void(omp_get_thread_num));
PAPI_create_eventset (&EventSet[t]));
PAPI_add_event (EventSet[t], PAPI_FP_OPS));
PAPI_start (EventSet[t]);
```

- PAPI multiplexing handled automatically, if needed

PAPI details handled by GPTL (cont'd)

- And these subsequent calls:

```
GPTLstart ("timer_name");

GPTLstop ("timer_name");
```

- Imply:

```
PAPI_read (EventSet[t], counters);
```

- Also implied part of GPTLstop:

```
sum[n] += counters[n] - countersprv[n];
```

Derived events

Computational Intensity:

```
if (GPTLsetoption (GPTL_CI, 1) != 0);

if (GPTLsetoption (PAPI_FP_OPS, 1) != 0);

if (GPTLsetoption (PAPI_L1_DCA, 1) != 0);

if (GPTLinitialize () != 0);

(...)

ret = GPTLstart ("millionFPOPS");

for (i = 0; i < 1000000; ++i)

  arr1[i] = 0.1*arr2[i];

ret = GPTLstop ("millionFPOPS");
```

Results:

```
Stats for thread 0:

             Called Recurse Wallclock max       min       CI       FP_OPS    L1_DCA

  millionFPOPS       1    -       0.006     0.006     0.006 5.00e-01 1.00e+06 2.00e+06

Total calls           = 1

Total recursive calls = 0
```

Auto-instrumentation

Works with GNU, PathScale, and PGI (PGI >= 8.0.2)

```
# gcc -g -finstrument-functions *.c -lgptl
# gfortran -g -finstrument-functions *.f90 -lgptl
# pgcc -g -Minstrument:functions *.c -lgptl
```

Inserts automatically at function start:

```
__cyg_profile_func_enter (void *this_fn, void *call_site);
```

And at function exit:

```
__cyg_profile_func_exit (void *this_fn, void *call_site);
```

Auto-instrumentation (cont'd)

GPTL handles these entry points with:

```
void __cyg_profile_func_enter (void *this_fn,
                               void *call_site)
{
  (void) GPTLstart_instr (this_fn);
}
```

Auto-instrumentation (cont'd)

User needs to add only:

```
program main
   ret = gptlsetoption (PAPI_FP_OPS, 1)
   ret = gptlinitialize ()
   call do_work ()     ! Lots of embedded subroutines
   call gptlpr (iam)
   stop 0
end program main
```

Raw auto-instrumented output

```
Stats for thread 0:

                    Called Recurse Wallclock max       min       % of   pop UTR Overhead    FP_INS e6 / sec
  pop                    1   -     290.307   290.307   290.307     100.00         0.000 1.61e+09      5.55
    80ee040              1   -      35.855    35.855    35.855      12.35         0.000 3.52e+06      0.10
      81593b0            1   -       2.681     2.681     2.681       0.92         0.000         5     0.00
        8158e60          1   -       0.050     0.050     0.050       0.02         0.000         1     0.00
      8104840            1   -       0.089     0.089     0.089       0.03         0.000        25     0.00
*     81571d0          460   -       0.038     0.001     0.000       0.01         0.001       460     0.01
*     8157250           30   -       0.002     0.000     0.000       0.00         0.000        30     0.01
*     81572e0           60   -       0.005     0.000     0.000       0.00         0.000        60     0.01
      8065270            1   -       0.000     0.000     0.000       0.00         0.000         1     0.01
      80751a0            1   -       0.012     0.012     0.012       0.00         0.000        57     0.00
        8158d60          1   -       0.000     0.000     0.000       0.00         0.000         1     0.06
        80644b0          1   -       0.001     0.001     0.001       0.00         0.000         1     0.00
      80a8890            1   -       0.026     0.026     0.026       0.01         0.000     62289     2.44
        80a5740          2   -       0.006     0.003     0.003       0.00         0.000     27538     4.72
        80a5e40          2   -       0.004     0.004     0.000       0.00         0.000     61322    14.46
      8075e60            1   -      17.820    17.820    17.820       6.14         0.000 2.10e+06      0.12
•     8064e50       536794   -       6.840     0.000     0.000       2.36         0.676    536794     0.08
```

Converting instrumented output

- To turn addresses back into names:

```
# hex2name.pl [-demangle] <executable> <timing_file>
```

- Uses “nm” to find the entry point names corresponding to printed addresses

Converted auto-instrumented output

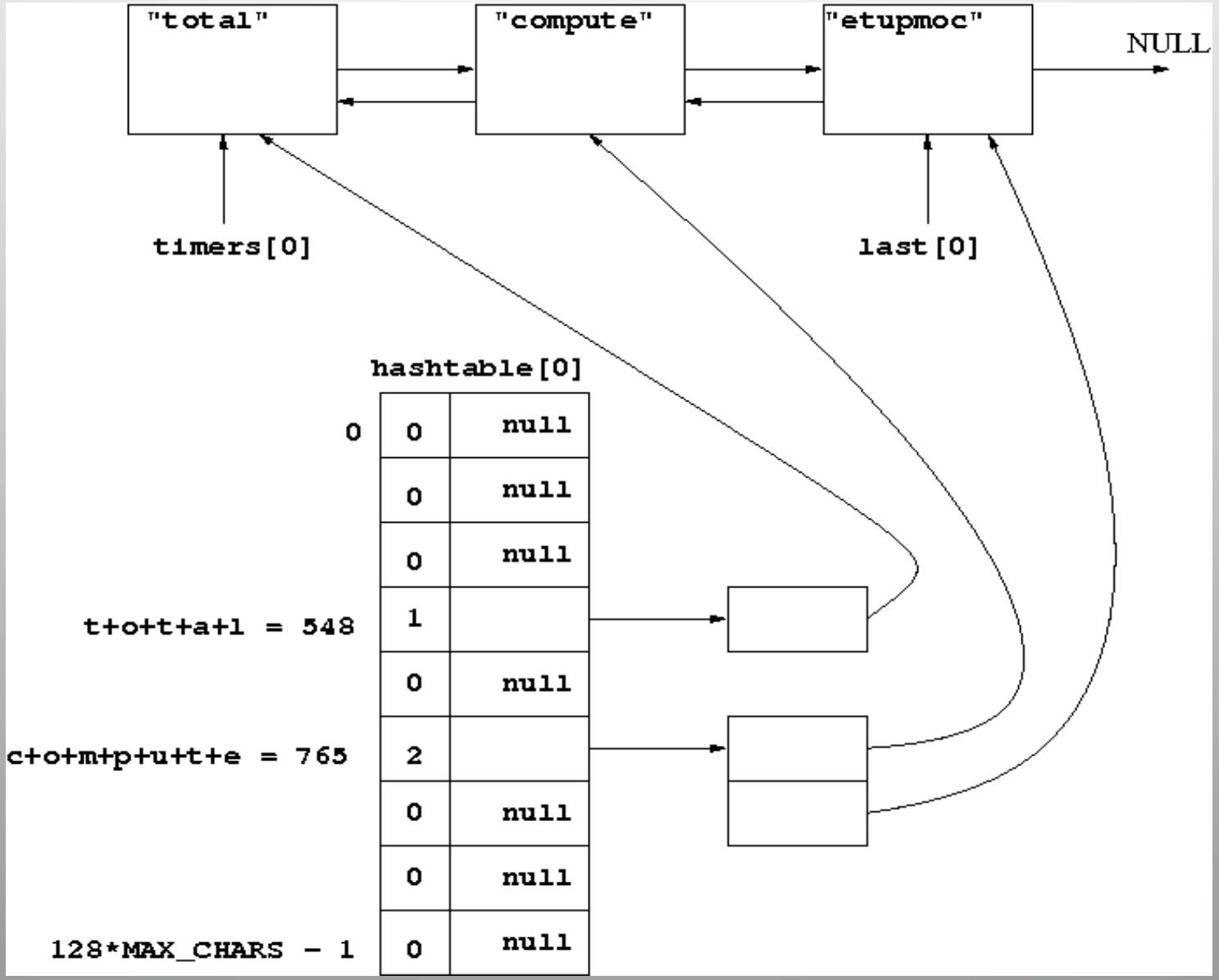
Stats for thread 0:

	Called	Recurse	Wallclock	max	min	% of pop	FP_INS	e6 / sec
pop	1	-	290.307	290.307	290.307	100.00	1.61e+09	5.55
INITIALIZE_POP.in.INITIAL	1	-	35.855	35.855	35.855	12.35	3.52e+06	0.10
INIT_COMMUNICATE.in.COMMUNICATE	1	-	2.681	2.681	2.681	0.92	5	0.00
CREATE_OCN_COMMUNICATOR.in.COMM	1	-	0.050	0.050	0.050	0.02	1	0.00
INIT_IO.in.IO_TYPES	1	-	0.089	0.089	0.089	0.03	25	0.00
* BROADCAST_SCALAR_INT.in.BROADCA	460	-	0.038	0.001	0.000	0.01	460	0.01
* BROADCAST_SCALAR_LOG.in.BROADCA	30	-	0.002	0.000	0.000	0.00	30	0.01
* BROADCAST_SCALAR_CHAR.in.BROADC	60	-	0.005	0.000	0.000	0.00	60	0.01
INIT_CONSTANTS.in.CONSTANTS	1	-	0.000	0.000	0.000	0.00	1	0.01
INIT_DOMAIN_BLOCKS.in.DOMAIN	1	-	0.012	0.012	0.012	0.00	57	0.00
GET_NUM_PROCS.in.COMMUNICATE	1	-	0.000	0.000	0.000	0.00	1	0.06
CREATE_BLOCKS.in.BLOCKS	1	-	0.001	0.001	0.001	0.00	1	0.00
INIT_GRID1.in.GRID	1	-	0.026	0.026	0.026	0.01	62289	2.44
HORIZ_GRID_INTERNAL.in.GRID	2	-	0.006	0.003	0.003	0.00	27538	4.72
TOPOGRAPHY_INTERNAL.in.GRID	2	-	0.004	0.004	0.000	0.00	61322	14.46
INIT_DOMAIN_DISTRIBUTION.in.DOM	1	-	17.820	17.820	17.820	6.14	2.10e+06	0.12
• GET_BLOCK.in.BLOCKS	536794	-	6.840	0.000	0.000	2.36	536794	0.08

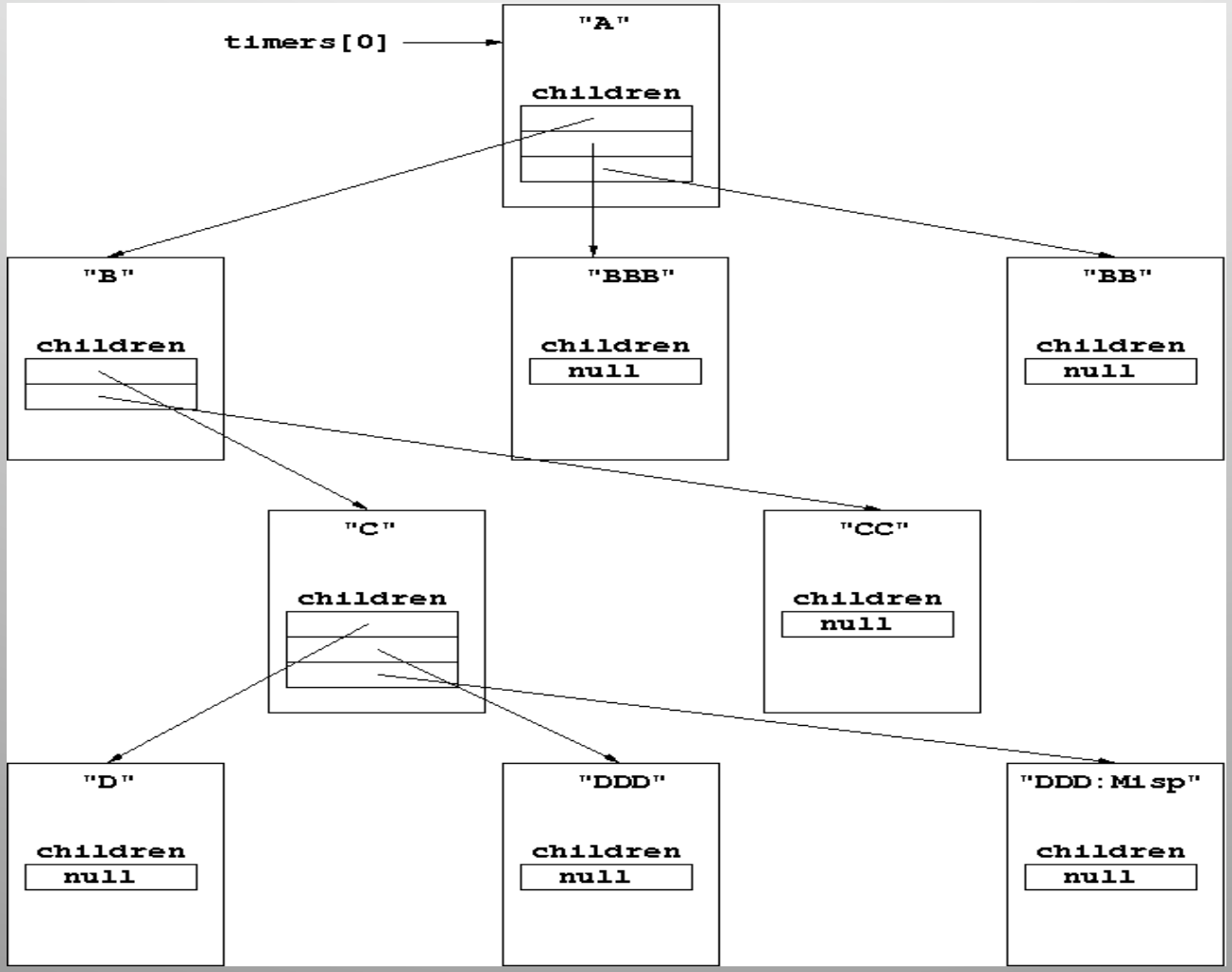
Multiple parent information

```
  2 INIT_IO.in.IO_TYPES
  3 INIT_DOMAIN_BLOCKS.in.DOMAIN
  1 INIT_GRID1.in.GRID
  5 READ_HORIZ_GRID.in.GRID
  2 READ_TOPOGRAPHY.in.GRID
662 INIT_DOMAIN_DISTRIBUTION.in.DOMAIN
  2 READ_VERT_GRID.in.GRID
  2 READ_BOTTOM_CELL.in.GRID
 45 AREA_MASKS.in.GRID
 11 INIT_TIME1.in.TIME_MANAGEMENT
  4 INIT_STATE.in.STATE_MOD
  2 INIT_TOPOSTRESS.in.TOPOSTRESS
  .....
  2 INIT_TAVG.in.TAVG
  2 INIT_MOORING.in.MOORINGS
932   BROADCAST_SCALAR_INT.in.BROADCAST
```

Internal data structures



Internal data structures (cont'd): Preserving parent-child relationships



Examining Load Imbalance

```
GPTLstart ("total");
GPTLstart ("sleep(iam)");
sleep (iam);   // Do some load-imbalanced work
GPTLstop ("sleep(iam)");

GPTLstart ("sleep(1)");
MPI_Bcast (&ret, 1, MPI_INT, commsize - 1,MPI_COMM_WORLD);
sleep (1);
GPTLstop ("sleep(1)");
GPTLstop ("total");
```

Results

```
Process 0:

                     Called Recurse Wallclock  TOT_INS e6 / sec
  total                   1    -       3.983 1.24e+09   311.55
    sleep(iam)            1    -       0.000      968   161.33
    sleep(1)              1    -       3.982 1.24e+09   311.56


Process 3:

                     Called Recurse Wallclock  TOT_INS e6 / sec
  total                   1    -       4.027     6863     0.00
    sleep(iam)            1    -       3.017     1233     0.00
    sleep(1)              1    -       1.010     1592     0.00
```

Examining Load Imbalance (cont'd)

```
GPTLstart ("total");

GPTLstart ("sleep(iam)");

sleep (iam);          // Do some load-imbalanced work

GPTLstop ("sleep(iam)");

if (barriersync) {

  GPTLstart ("barriersync");

  MPI_Barrier (MPI_COMM_WORLD);

  GPTLstop ("barriersync");

}

GPTLstart ("sleep(1)");

MPI_Bcast (&ret, 1, MPI_INT, commsize - 1,
 MPI_COMM_WORLD);

sleep (1);            // Proxy for real work

GPTLstop ("sleep(1)");

GPTLstop ("total");
```

Results (barriersync = true)

Process 0:

	Called	Recurse	Wallclock	TOT_INS	e6 / sec
total	1	-	3.997	1.19e+09	297.52
sleep(iam)	1	-	0.000	969	138.43
barriersync	1	-	2.986	1.19e+09	398.27
sleep(1)	1	-	1.011	1416	0.00

Process 3:

	Called	Recurse	Wallclock	TOT_INS	e6 / sec
total	1	-	4.016	11723	0.00
sleep(iam)	1	-	3.006	1235	0.00
barriersync	1	-	0.000	3059	61.18
sleep(1)	1	-	1.010	1595	0.00

Aggregating across MPI tasks

- To compute stats across all threads and tasks:

```
# parsegptlout.pl [-c column] <region_name>
```

- E.g. for the POP run earlier:

```
# parsegptlout.pl -c 1 ELLIPTIC_SOLVERS
```

```
Found 192 calls across 192 tasks and 1 threads per task
192 of a possible 192 tasks and threads had entries for ELLIPTIC_SOLVERS
Heading is Wallclock
Max   = 78.257 on thread 0 task 128
Min   = 76.746 on thread 0 task 35
Mean  = 77.161
Total = 14814.932
```

Utility functions

- **Print current process memory usage stats:**

```
GPTLprint_memusage ("after malloc");

after malloc size=26139 rss=199 share=140 text=1 datastack=0
```

- **Get wallclock, usr, sys timestamps:**

```
GPTLstamp (&wallclock, &usr, &sys);
```

- **Get current stats for a timer:**

```
GPTLquery ("timer_name",...);
```

Future Work

- More derived events
- Automation of hands-off profiling (similar to Phil Mucci's `papiex` tool)
- XML output
- MPI hooks

Download/access info

- Tar file and web-based documentation:
  - www.burningserver.net/rosinski/gptl
- On ORNL XT4/XT5:
  - module load gptl