Software Environment

IBM

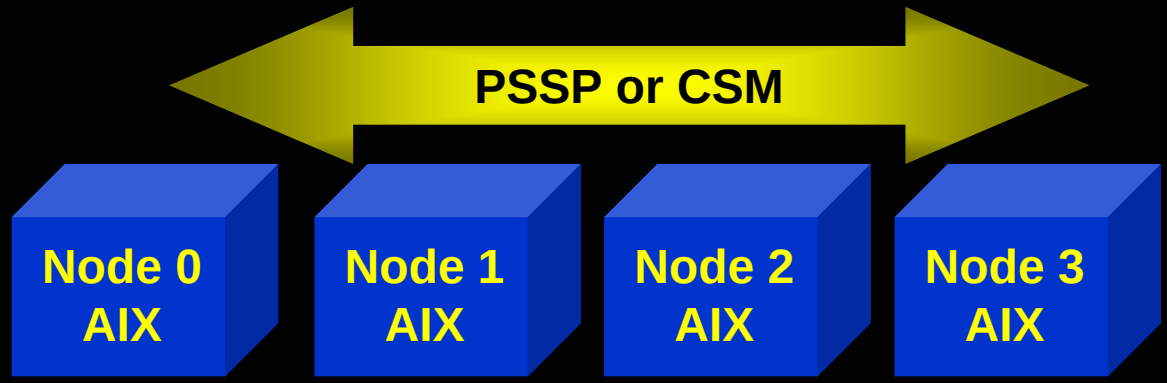
July, 2006

Agenda

- AIX
- Performance Monitors
- Development tools
- Debuggers

Operating System Software

- Server OS
  - AIX (Advanced Interactive eXecutive)
    - AT&T System V
  - Journaled
- Cluster System Management (CSM)
  - Management of distributed or clustered servers
- Parallel System Support Program (PSSP)
  - Predecessor to CSM
- Parallel Environment (PE)



HPC Software Stack

- Batch queuing:
  - LoadLeveler
- Parallel file system:
  - General Parallel File System (GPFS)
- MPI tools and library:
  - Parallel Environment (PE)
- Math library:
  - Engineering and Scientific Software Library (ESSL)

AIX Operating System

- AIX 5L
  - Current (new) generation of IBM's Unix
    - Linux “affinity”
    - Combines Unix technologies of AIX and Linux
- Current Versions:
  - AIX 5L version 5.2
  - AIX 5L version 5.3

Getting to know your system

- uname –a
- oslevel –f -r
- df
  - lspv ...
  - lslv ...
  - lsvg ...
- ifconfig –a; netstat -i
- lsdev –C | grep proc | wc –l
- lsattr -E –l proc0 –a type
- /usr/bin/pmcycles
  - Install bos.pmapi
- lsattr -E -l mem0 -a size
- prtconf

Parallel Environment (PE)

- Develop, debug, analyze, tune, and execute parallel applications
  - Parallel Operating Environment (POE)
  - MPI
    - Optimized for IBM switches and nodes
  - pdbx (Parallel Debugger)
    - Attach to running process
  - Parallel utilities, for easing file manipulation

PE Example

```
**************************************************************
c* Hello World Fortran Example
c To compile: mpxlf_r -o hello_world_f hello_world.f f
c**************************************************************
c
      program hello
      implicit none
      write(6,*) 'Hello, World!'
      stop
      end
```

PE Example

Host.list:

Node1

Node1

Node2

Node2

$ xlc –o hello_world hello_world.c

$ export MP_HOSTFILE=$PWD/host.list

$ poe hello_world -procs 4

Hello, World!

Hello, World!

Hello, World!

Hello, World!

AIX Characteristics

- Journaled file system
  - JFS and JFS2
  - File coherency
- Other AIX'isms and terms
  - LPP - Licensed Program Product (/usr/lpp/...)
  - BOS - Base Operating System (bos.rte, bos.up, etc)
  - Administration:
    - PTF- A specific software patch
    - APAR - A software fault or enhancement description
    - EFIX -An emergency software fix, invalidated
- Note: New process for delivering fixes
  - Sets of fully tested combinations of updates

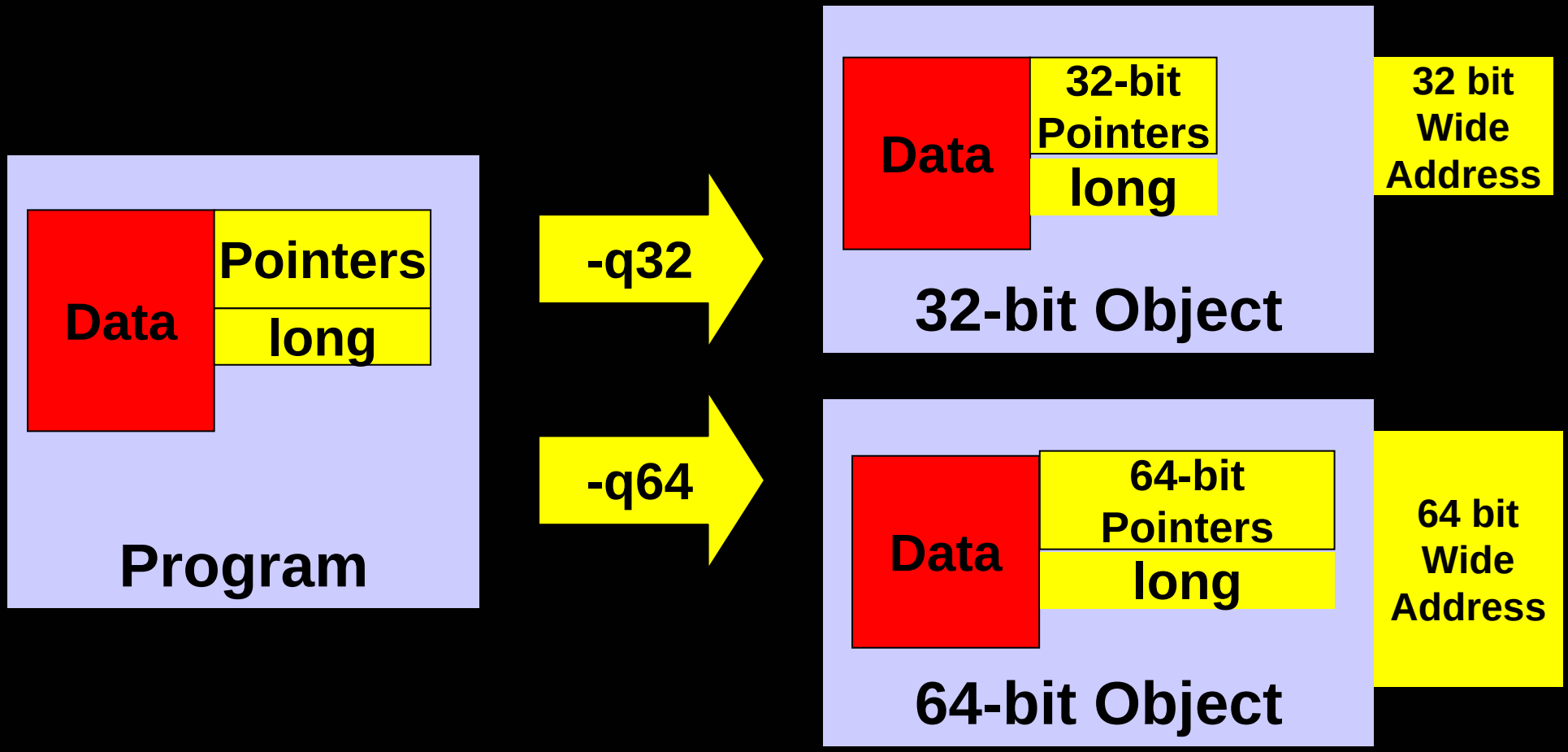
Linux Affinity

- AIX bias toward “Linux – like” environment
- Emerging Linux applications
- GNU tools
- GNU utilities
- Linux look & feel

64-bit Operating System

- Operating system address modes:
  - 32-bit kernel
    - Limitation: 96 Gbyte memory
    - Built -qarch=com
  - 64-bit kernel
    - No limitations
    - Built -qarch=ppc
- Hardware:
  - 64-bit design
- Software:
  - 32-bit model (default)
  - 64-bit model

Application Address Mode



Application address mode is independent of operating system address mode

Even more on 64-bit...
(because it is so often confused)

- 64-bit floating point representation is higher precision
  - Fortran: REAL*8, DOUBLE PRECISION
  - C/C++: double
  - You can use 64-bit floating point with –q32 or –q64

- 64-bit addressing is totally different. It refers to how many bits are used to store memory addresses and ultimately how much memory one can access.
  - Compile and link with –q64
  - Use `file a.out myobj.o` to query addressing mode

- The AIX kernel can be either a build that uses 32-bit addressing for kernel operations or uses 64-bit addressing, but that does not affect an application's addressibilty.
  - ls –l /unix to find out which kernel is used
  - Certain system limits depend on kernel chosen

One more thing about 64-bit…

- If you use –q64:
  - You can use lots of memory
  - INTEGER*8 or long long operations are faster
- If you use –q32:
  - You may run a few percent faster
    - Fewer bytes are used storing and moving pointers
  - You will have to learn about –bmaxdata
    - AIX link option
    - -bmaxdata:0x10000000 = 256 Mbyte = default
    - -bmaxdata:0x80000000 = 2 Gbyte
    - -bmaxdata:0xC0000000 = not widely publicized trick to use more than 2 Gbyte with –q32
      - "C" is the maximum
  - -q64
    - –bmaxdata:0 = default = unlimited
    - Other –bmaxdata values will be enforced if set

Essential Commands

- Software interrogation
- Hardware interrogation
- System management

Hardware Configuration
lscfg: Installed resource list

```
/home/myuid$ lscfg
INSTALLED RESOURCE LIST

The following resources are installed on the machine.
+/- = Added or deleted from Resource List.
*   = Diagnostic support not available.

  Model Architecture: chrp
  Model Implementation: Multiple Processor, PCI bus

+ sysplanar0        00-00          System Planar
+ mem0              00-00          Memory
+ proc0             00-00          Processor
+ L2cache0          00-00          L2 Cache
```

Software Configuration
lslpp: Installed Software

```
/home/myuid$ lslpp -L
 Fileset                 Level  State  Description
 ----------------------------------------------------------
 Adobe.acrobat   3.0.1.0    C    Adobe acrobat reader
 DB2V5CAE.Bnd    5.2.0.0    C    DB2 Client Application
 DB2V5SERV.Bnd   5.2.0.0    C    DB2 Server(s) Software
 IBMVJava.dab.adt 2.0.0.0   C    VisualAge for Java
 IBMVJava.dab.rte 2.0.0.0   C    VisualAge for Java
```

Configuration Report

- prtconf
  - Print Configuration
  - Standard Unix command
- Information
  - Processors
  - Memory
  - Operating system

prtconf

```
$ prtconf -ckLms
CPU Type: 64-bit
Kernel Type: 32-bit
LPAR Info: 1 NULL
Memory Size: 131072 MB
Processor Clock Speed: 1900 MHz
```

System Management Installation Tool (SMIT or SMITTY)

```
Move cursor to desired item and press Enter.

  Software Installation and Maintenance
  Software License Management
  Devices
  System Storage Management (Physical & Logical
  Storage)
 ...
  Problem Determination
  Performance & Resource Scheduling
..
  Applications

F1=Help                F2=Refresh              F3=Cancel
  F8=Image
F9=Shell               F10=Exit                Enter=Do
```

Performance Monitors

- System (node) performance
  - topas
    - Similar to Linux “top”
    - Root user has to invoke first time to create a file in /etc
  - nmon
    - Freeware from IBM UK
  - vmstat
    - virtual memory statistics

Topas

```
magnet                averages:  7.90,  7.90,  7.38
Cpu states:       ...system,   0.0% wait,  50.0% idle
Real memory:      ...procs  512.0M files 2544.0M total
Virtual memory:   ... used   150.2M total

   PID USER      ...STAT      TIME   CPU% COMMAND
 30972 myusrid   ... run       0:22  50.0% lu.W
   516 root      ... run     591:16  49.5% Kernel (wait)
 23950 myusrid   ... run       0:00   0.4% monitor4.1
   774 root      ... run     568:46   0.0% Kernel
```

nmon

- Performance tuning utility
- Freeware, AIX and Linux
- Performance data:
  - CPU utilization
  - Memory use
  - Kernel statistics and run queue information
  - Disks I/O rates, transfers, and read/write ratios
  - Free space on file systems
  - Disk adapters
  - Network I/O rates, transfers, and read/write ratios
  - Paging space and paging rates
  - Etc.

Virtual Memory STATistics: vmstat

- System (node) resources
  - Memory
  - Page faults
  - CPU

```
$ vmstat 1
kthr     memory   faults    cpu
----- ----------- ------ -----------
 r   b    avm    fre    ...   us sy id wa
 0   0 70893 364069   ...    3  2 92  2
24   1 70894 364068   ...   35 65  0  0
25   2 70895 364067   ...   37 63  0  0
```

Application Performance Monitors

- User (application) performance
  - xprofiler
  - tprof
    - Very much improved in AIX 5.3
- Performance Monitor Tools
  - hpmcount
  - hpmstat
  - pmcycles
  - pmlist

Xprofiler

- Compile, link, execute:
  - $ xlf .... -g -pg ... # "-g" enables histograming
  - $ a.out # →gmon.out file is produced
- Analyze:
  - $ xprofiler a.out gmon.out # GUI interface
  - $ gprof > gprof.report ! text report # Text
- Time sample interval: 0.01 sec.
- MPI codes generate "N" gmon.out files

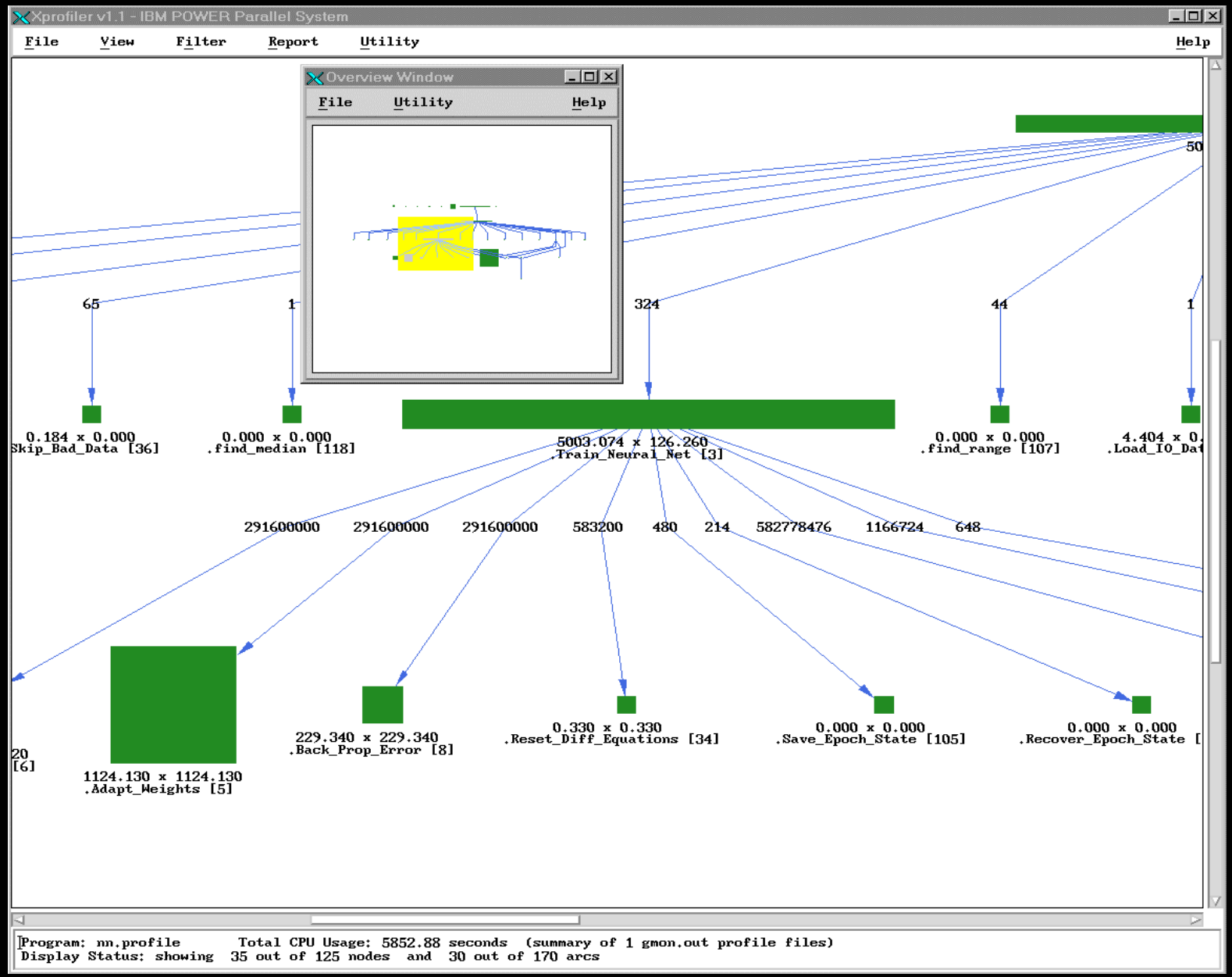
Xprofiler Tips

- Text mode:
  - use gprof
  - Libraries must match across systems.
- Flat profile:
  - Select "Report"...
- Drill:
  - Right click on routine
  - Select "Code Display" for a source-code view
  - Use "File ; Set File Search Paths" to set source directory
- Graphical Display:
  - Width of a bar: time including called routines
  - Height of a bar: time excluding called routines

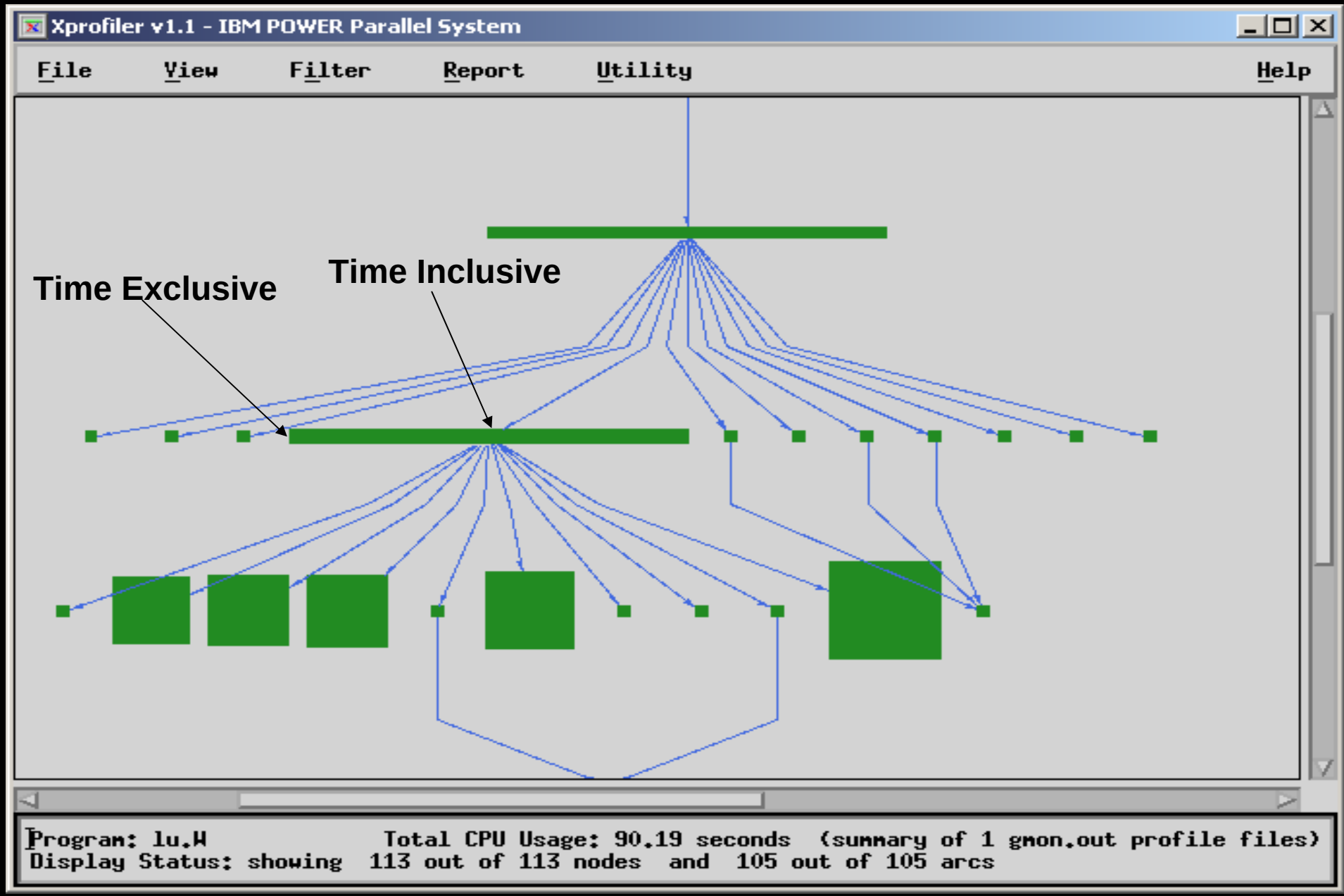
Xprofiler Tips (continued)

- Select:
  - Filter ; Uncluster Functions
  - Filter ; Hide All Library Calls
- Select:
  - Filter ; Filter by CPU Time
  - Filter ; by Call Count
- If xprofiler fails with "bad font" error message:
  - 1.) edit /usr/lib/X11/app-defaults/Xprofiler
    - replace *narc*font: -ibm-block-…
    - with *narc*font: fixed
  - 2.) xrdb -load /usr/lib/X11/app-defaults/Xprofiler

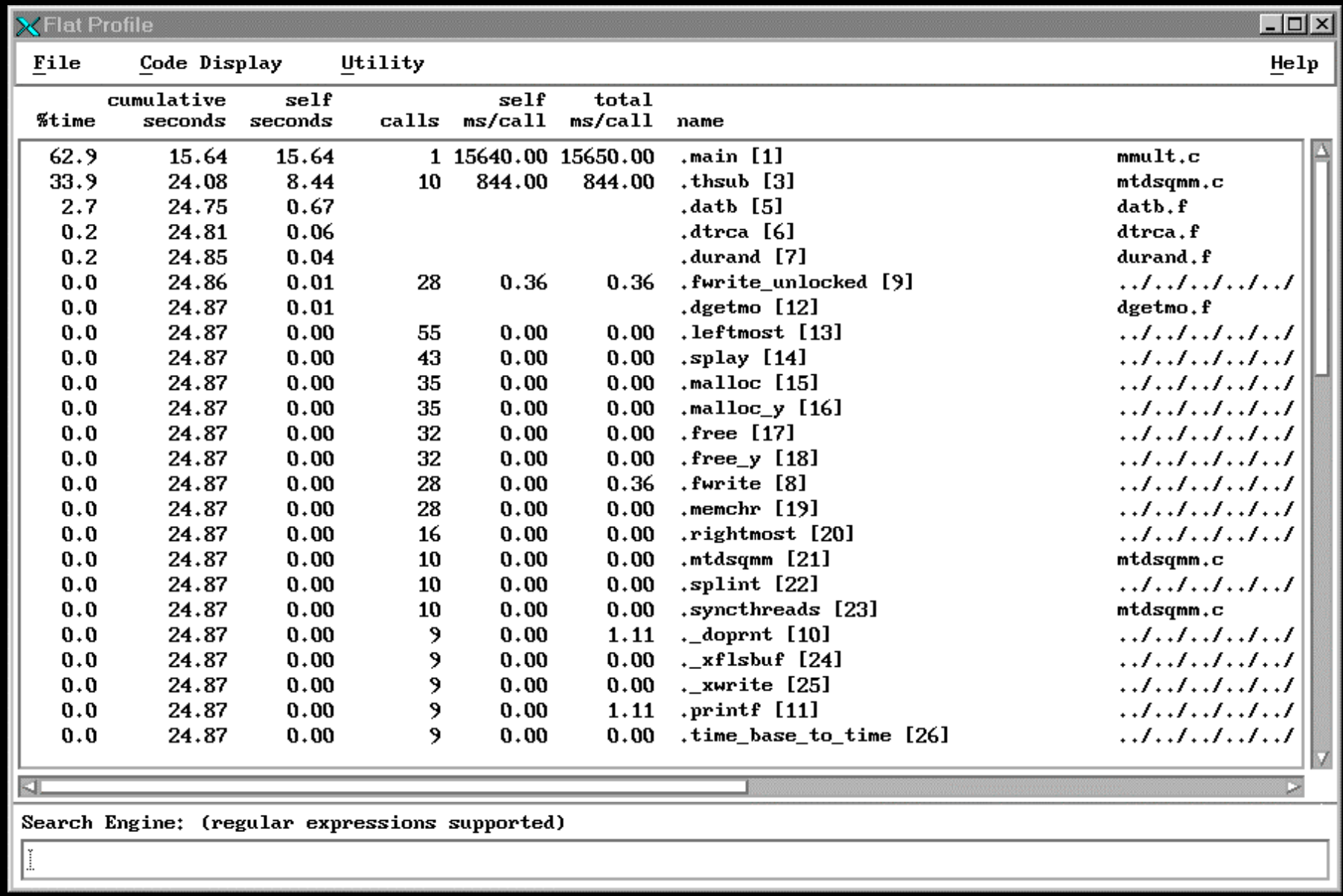
Xprofiler: Initial Screen



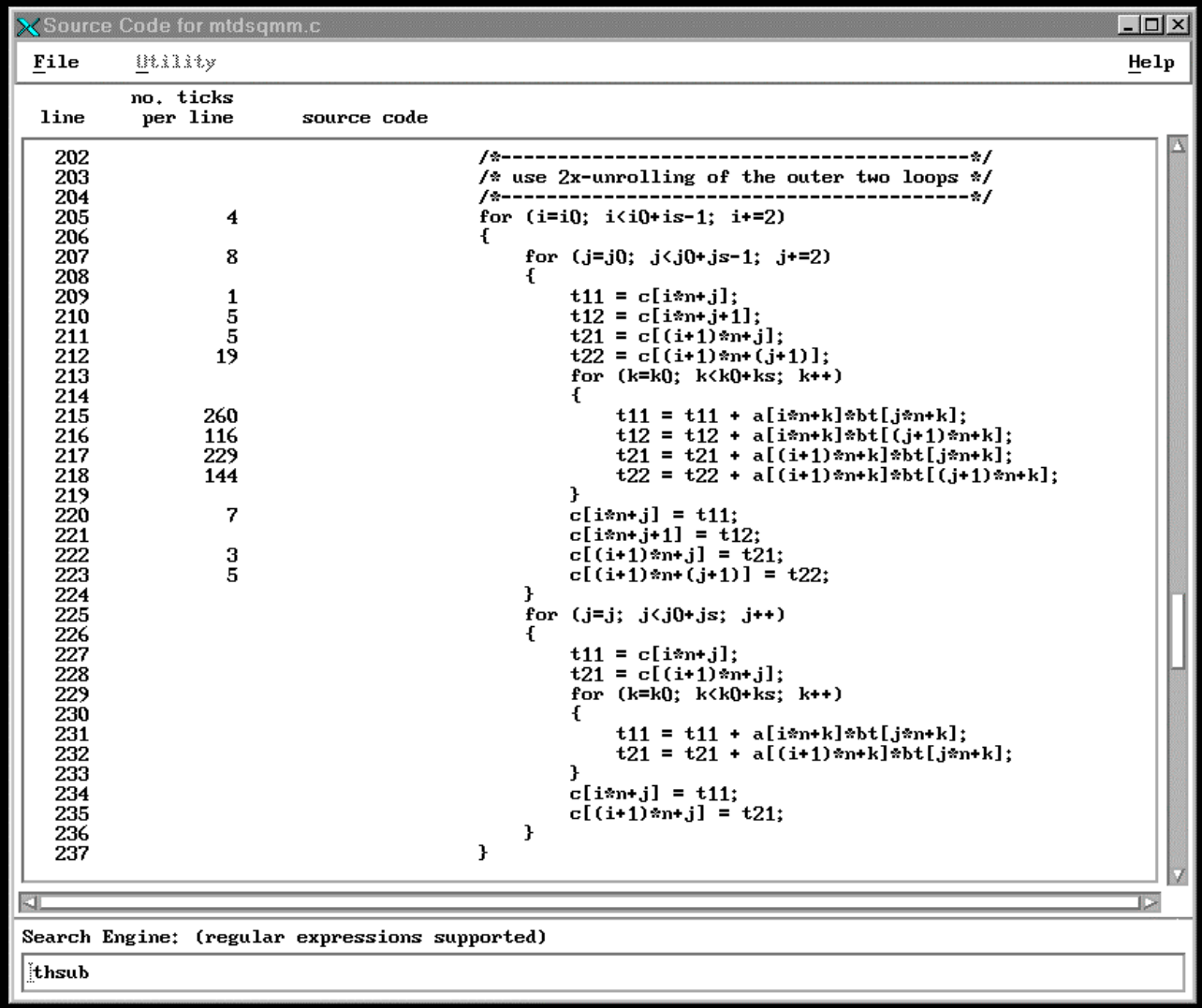
Xprofiler: Example



Xprofiler: Flat Profile

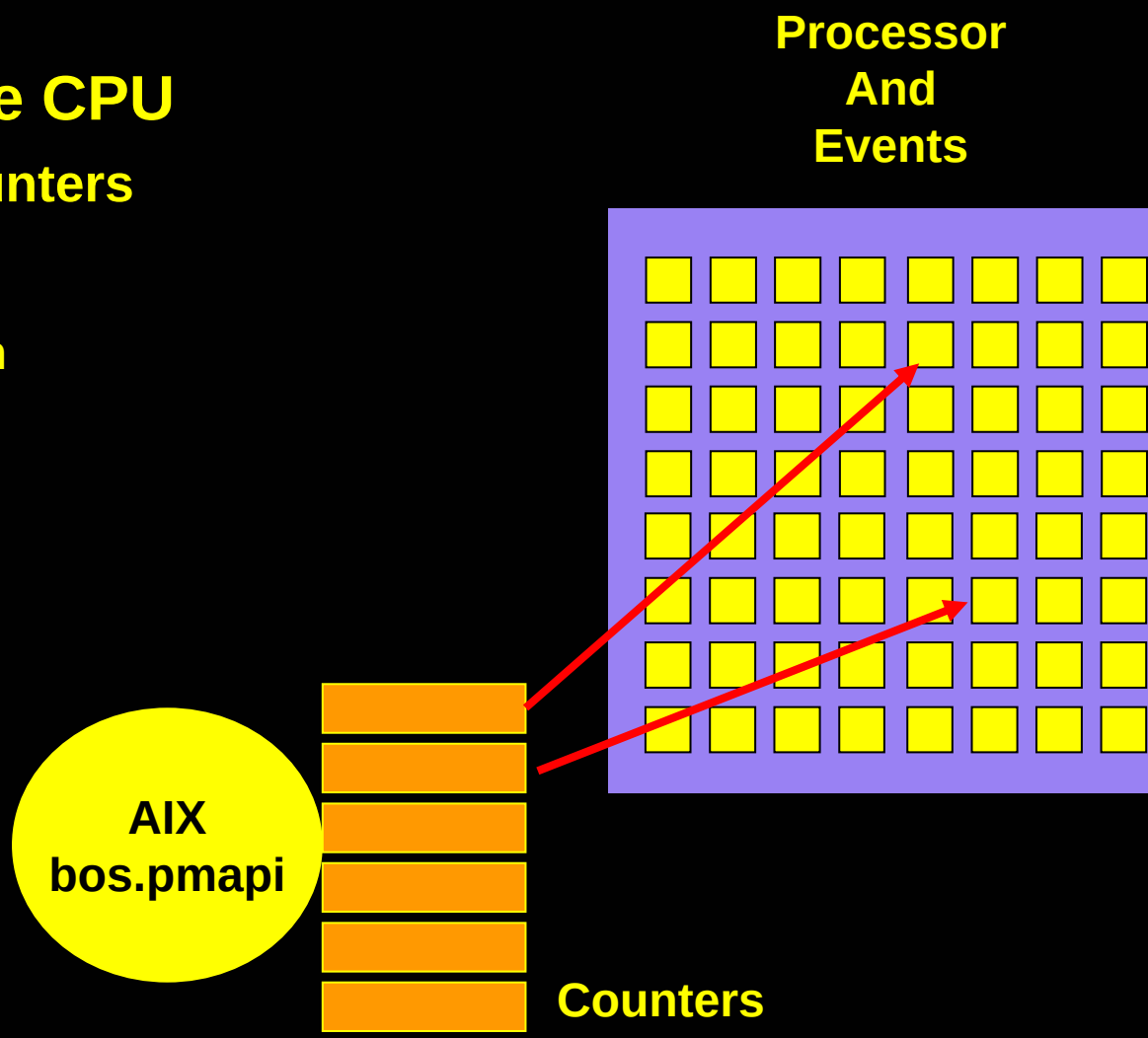


Xprofiler: Source Code View



Hardware Performance Monitor

- Counters are built into the CPU
  - More than 250 (relevant) counters
  - Accessible through library
    - Require AIX kernel extension
    - Default in AIX 5
  - Accurate counts, but...
- Instrumentation
  - Whole program
  - Instrumentation point
- Text output
- GUI output



Hardware Performance Monitor and Tools

- Contained in bos.pmapi file set
- System-level APIs
  - Allow counting of events
    - Whole machine
    - Set of processes with a common ancestor.
- First party kernel-thread-level APIs
  - Allow threads to count their own activity
- Third party kernel-thread-level APIs
  - Allow a debug program to count the activity of target threads

Hardware Performance Monitor Tools

- pmcycles
- pmlist
- hpmcount
- hpmstat

pmcycles

- Returns the processor clock and decrementer speeds

```
$ pmcycles -d -m
Cpu 0 runs at 1656 MHz
Cpu 1 runs at 1656 MHz
Cpu 2 runs at 1656 MHz
Cpu 3 runs at 1656 MHz
Cpu 4 runs at 1656 MHz
Cpu 5 runs at 1656 MHz
Cpu 6 runs at 1656 MHz
Cpu 7 runs at 1656 MHz
The decrementer runs at 207.1 MHz (4.83 ns per tick)
```

pmlist

- Information:
  - Processors
  - Events
  - Event groups
  - Derived metrics

```
$ pmlist
usage: pmlist -h
       pmlist -l [ -o t | c ]
       pmlist -s | -e <short|select> | -c counter[,event] | -g group | -S set | -D
DerivedMetric
              [-p procname] [-s] [-d] [-o t|c] [-f filter]
where:
   -h                this help screen
   -l                lists all supported processor types
   -s                displays processor information summary
   -e short|select   lists all events with this short name or select event value
   -c -1             lists all events for all counters
   ...
```

hpmstat

- System-wide event collection
  - Raw and derived metrics
- Default root user only

hpmcount

- Executes applications
- Provides
  - Wall clock time
  - Raw and derived metrics
  - Operating system resource-utilization statistics

```
$ hpmcount a.out
...
#######  End of Resource Statistics  ########
  …
  Utilization rate                          :         95.810 %
  MIPS                                      :       1294.629
  Instructions per cycle                    :          0.816
  HW Float point instructions per Cycle     :          0.526
  HW floating point / user time             :        870.450 M HWflop/sec
  HW floating point rate (HW Flops / WCT)   :        833.976 M HWflops/sec
```

hpmcount –s 1

```
$ hpmcount –s 1 a.out
Utilization rate                          :     98.474 %
  MIPS                                    :   2743.325
  Instructions per cycle                  :      1.465
  HW Float point instructions per Cycle   :      0.676
  HW floating point / user time           :   1285.383 M HWflop/sec
  HW floating point rate (HW Flops / WCT) :   1265.764 M HWflops/sec
```

hpmcount –s 2

Utilization rate	:	98.183 %
Total load and store operations	:	21967.949 M
Instructions per load/store	:	1.576
MIPS	:	2730.613
Instructions per cycle	:	1.462
% Instructions dispatched that completed	:	98.552 %

hpmcount –s 3

```
  Utilization rate                      :      98.293 %
  Total L2 data cache accesses          :    6276.074 M
  % accesses from L2 per cycle          :      26.594 %
  L2 traffic                            :  766122.306 MBytes
  L2 bandwidth per processor            :   60695.238 MBytes/sec
  MIPS                                  :    2742.726
  Instructions per cycle                :       1.467
```

hpmcount –s 4

```
number of loads per TLB miss          :    23797159.282
Total load and store operations       :       21980.992 M
Instructions per load/store           :           1.575
MIPS                                  :        2748.390
```

hpmcount –s 5

```
  Number of loads per TLB miss          :    23797159.282
  Total load and store operations       :       21980.992 M
  Instructions per load/store           :           1.575
  MIPS                                  :        2748.390
```

Debuggers

- Default (standard AIX):
  - dbx
  - pdbx
- Commercial:
  - TotalView
  - ddt

Debuggers

- Examine core file
  - "where"
- Start and run programs
- Attach to running programs
  - THIS IS COOL!
  - MPI program hangs? Use pdbx
- Program stop on specified conditions
- Examine stopped state
- Change things in program
  - Experiment with correcting the defects

AIX Default Debugger: dbx

- Symbolic debugger for languages:
  - C
  - C++
  - Fortran
- Examine object and core files
- Trace back
- Controlled breakpoints
- Syntax:
  - dbx [–a Process ID} [-r] … [Object file [corefile]]

Run Program Under dbx

```
$ dbx a.out
(dbx) run
Segmentation fault in test_sub at line 18 in file "testprog.f"
   18              array(1,1) = 1.

(dbx) where
test_sub(array = (...), nvar = 2, nrec = 3), line 18 in "testprog.f"
main(), line 10 in "testprog.f"

(dbx) print array(1,1)
reference through nil pointer
```

Attach Program Under dbx

```
$ ps
 UID    PID    TTY  TIME CMD
206 454854  pts/8  0:09 a.out
$ dbx -a 454854
Waiting to attach to process 454854 ...
Successfully attached to a.out.
reading symbolic information ...
stopped in __divi64 at 0xd03a9d64
0xd03a9d64 (__divi64+0xec) 41800010       blt   0xd03a9d74 (__divi64+0xfc)

(dbx) print icount
421440793
(dbx) print I
0
(dbx) assign I=4
(dbx) print I
4
```

Summary

- Operating system:
  - AIX (Unix)
- Components:
  - PSSP, PE, Batch Queue, XL compilers
- Interrogation tools:
  - lscfg, lslpp
- Performance analysis:
  - xprofiler
  - Hardware Performance Monitor
- Debugger:
  - dbx
  - TotalView