SCALE TO NEW HEIGHTS

Petascale Debugging with Allinea DDT

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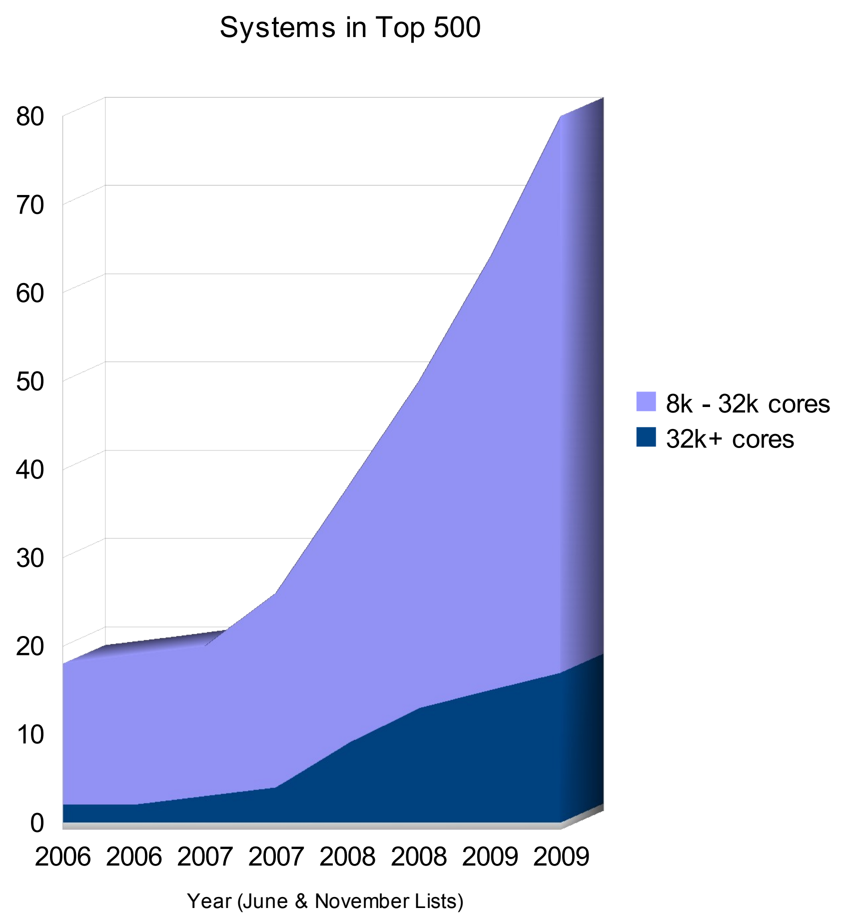
CTO

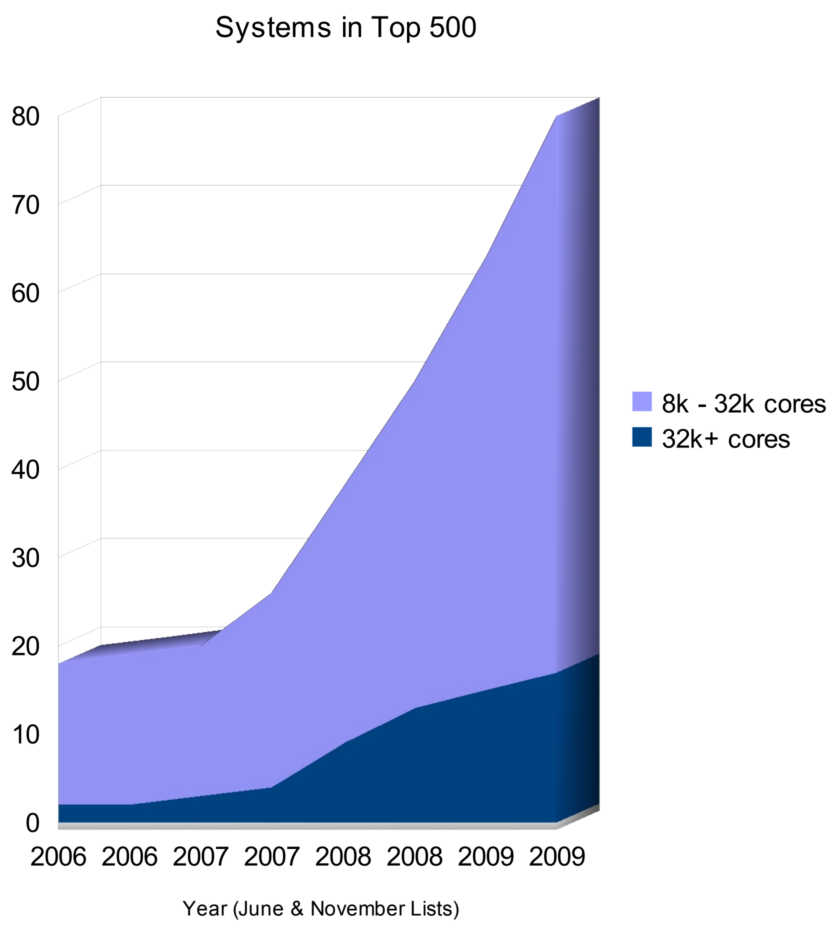
Interesting Times ...

- Processor counts growing rapidly
- GPUs entering HPC
- Large hybrid systems imminent
- But what happens when software doesn't work?



Why the graph?

- Debuggability
  - A subjective measure of the ability to be debugged
- Linear tool architectures
  - Linear (or worse) bottlenecks
  - Pain threshold varies: 1 second, 1 minute, 1 hour?
- A major problem
  - Previously exclusive to big labs
  - Now everyone is joining in the fun



Approaches to Scale

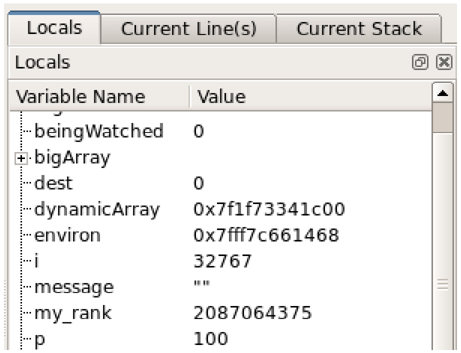
- Ignore the problem
  - Pretend bugs at scale do not happen
- Best programming practices
  - Consistency checking and self-diagnosis within code
  - Still frustrated by some types of bug
- Lightweight debugging
  - STAT (LLNL) identifies equivalent processes using stacks
  - STAT calls DDT (or TTV) to debug representatives
  - Other work is promising

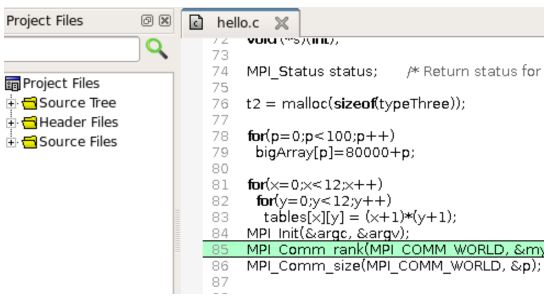
- But what about full-strength debuggers?

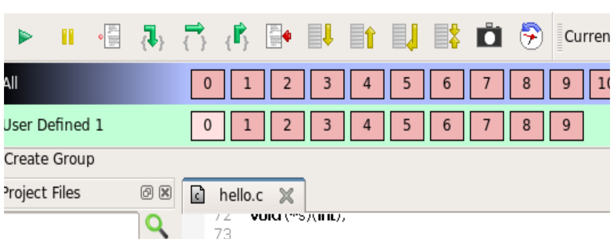
Full-strength Debugging

- Many benefits to graphical parallel debuggers
  - Large feature sets for common bugs
  - Richness of user interface and real control of processes
- Historically **all** parallel debuggers hit scale problems
  - Bottleneck at the frontend: Direct GUI → nodes architectures
    - Linear performance in number of processes
  - Human factors limit – mouse fatigue and brain overload
- Are tools ready for the task?
  - DDT has changed the game

DDT in a nutshell



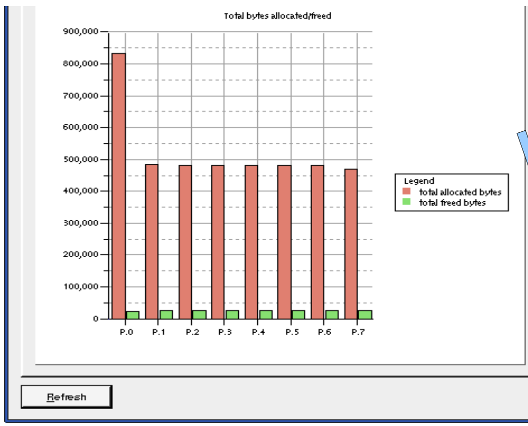


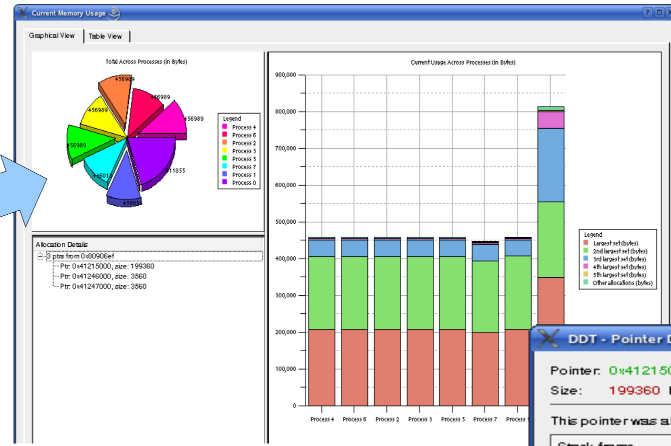


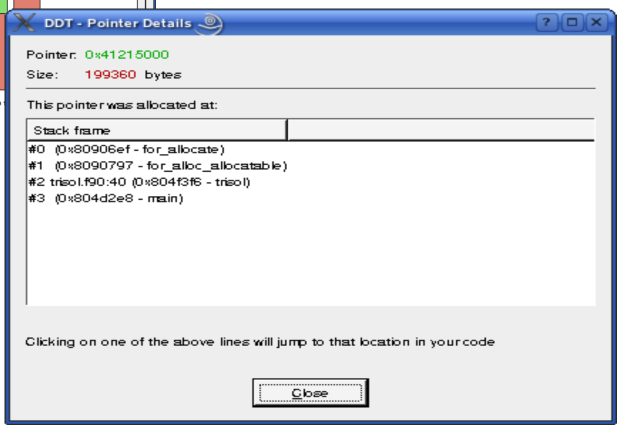
- Scalar features
  - Advanced C++ and STL
  - Fortran 90, 95 and 2003: modules, allocatable data, pointers, derived types
  - Memory debugging
- Multithreading & OpenMP features
  - Step, breakpoint etc. one or all threads
- MPI features
  - Easy to manage groups
  - Control processes by groups
  - Compare data
  - Visualize message queues

Memory Debugging

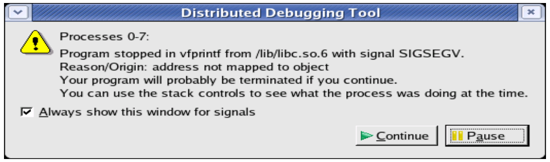
- Find memory leaks





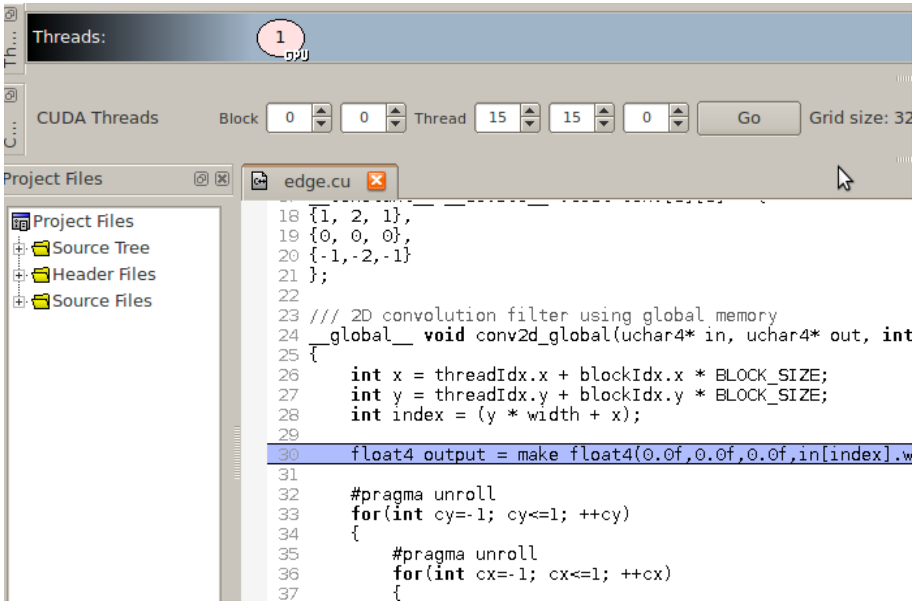


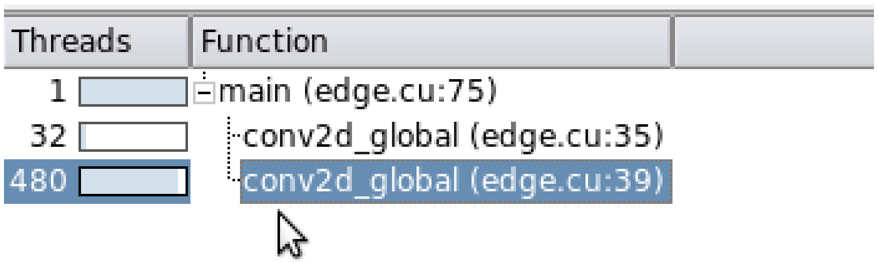
- Or stop on read/write beyond end of array



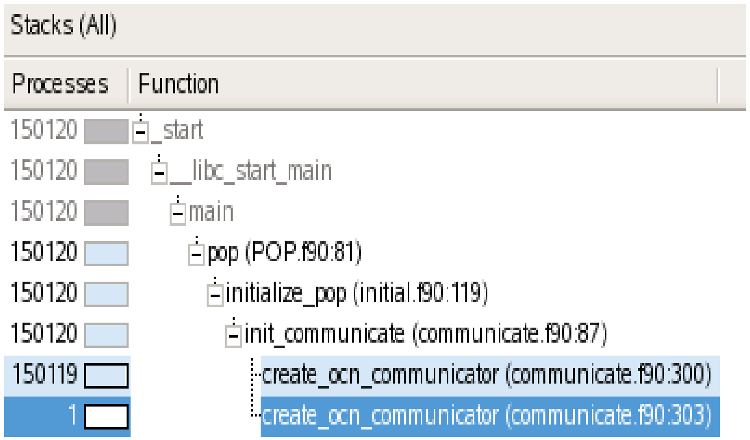
GPU Debugging

- Run the code
  - Browse source
  - Set breakpoints
  - Stop at a line of CUDA code
  - Stops once for each scheduled collection of blocks
- Select a CUDA thread
  - Examine variables and shared memory
  - Step a warp

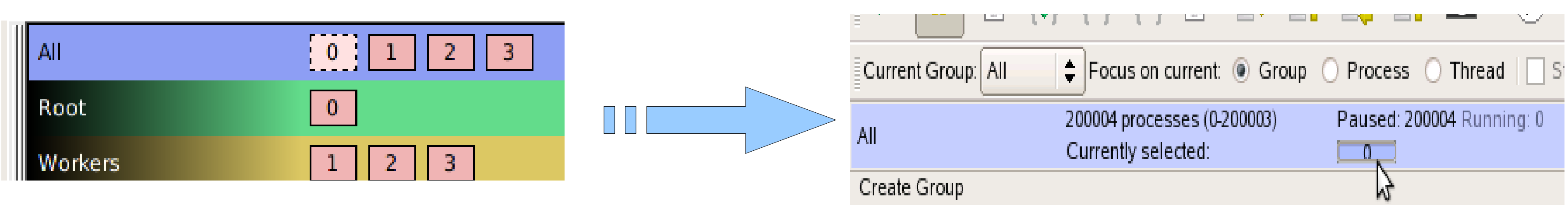




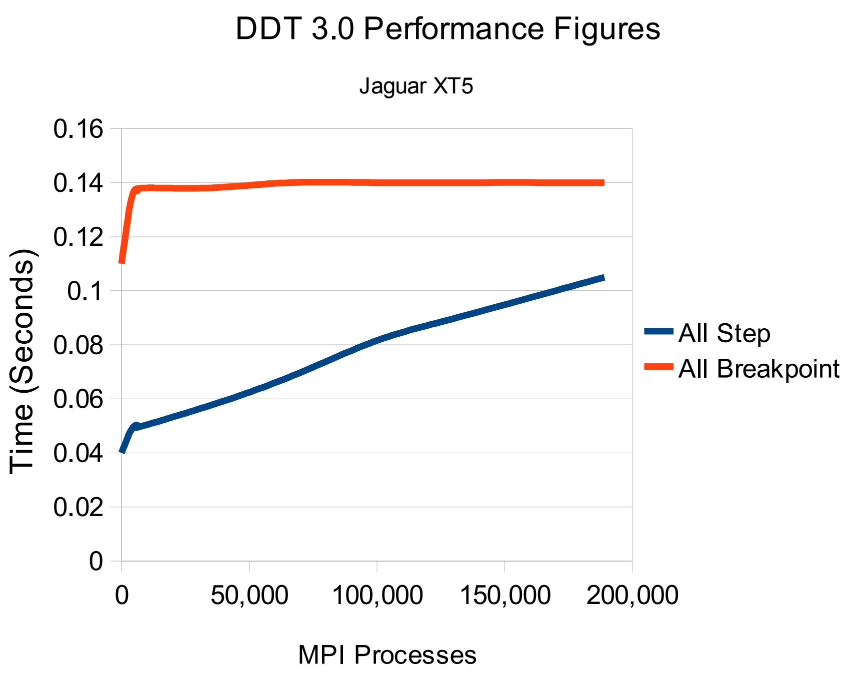
Scalable Process Control



- Parallel Stack View
  - Finds rogue processes faster
  - Identifies classes of process behaviour
  - Allows rapid grouping of processes
- Control Processes by Groups
  - Set breakpoints, step, play, stop etc. using user-defined groups
  - Mutates to scalable groups view
  - Compact group representations

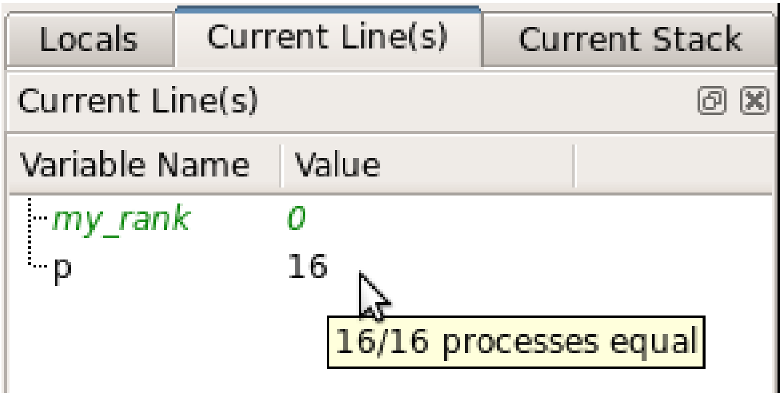


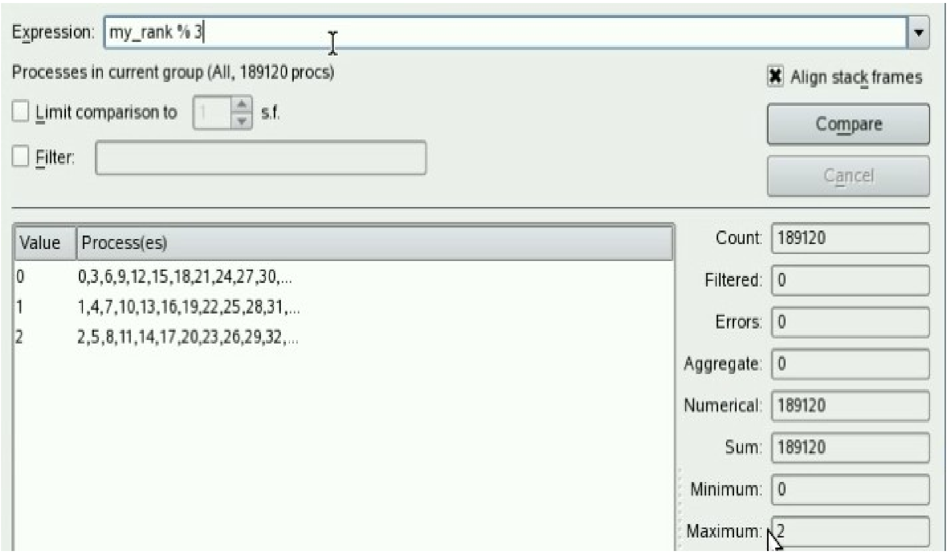
DDT: Petascale Debugging



- DDT is delivering petascale debugging **today**
  - Collaboration with ORNL on Jaguar Cray XT
  - Tree architecture – logarithmic performance
  - Many operations now faster at 220,000 than previously at 1,000 cores
  - **~1/10th of a second** to step and gather all stacks at 220,000 cores

Presenting Data, Usefully

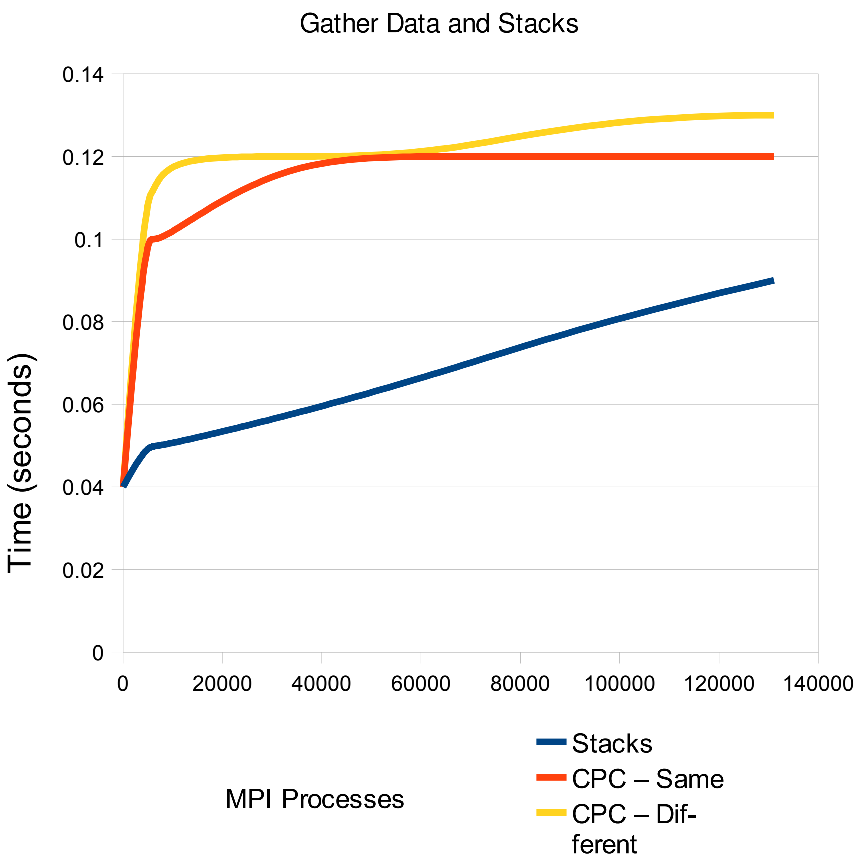




- Gather from every node
  - Potentially costly – if all data different
  - Easy if data mostly same
  - New ideas
    - Aggregated statistics
    - Probabilistic algorithms optimize performance – even in pathological case
- Watch this space!
  - With a fast and scalable architecture, new things become possible

Data Gathering Results

- Benchmarked on five codes on Jaguar XT
  - Stacks gathering mileage can vary: default install at ORNL has full debug info deep into MPI
  - Cross Process Comparison
    - Of equal variable
    - Of MPI rank (a bad case!)



The DDT Tree, In Brief

- Depth/width
  - Another gut feel pseudo calculation story ;-)
  - Override by environment variables
- Start up
  - Use vendor's fast transfer of topology file and daemons, where present
  - Each daemon connects to its parent
- Message aggregation/broadcast
  - Commands targeted to process sets, tree sends to intersect with children
  - Responses merged – but doesn't wait too long!
  - Ordered sets of process ranges

Current Status

- Most features now scale
  - Attach, run, process control and breakpoints
  - Process stacks
  - Data comparison
  - Memory debugging – out-of-bound array access, leaks, etc.
  - Import/export – stacks (XML/CSV), arrays, compared data
  - Tested at 220k cores on XT; 8k on Blue Gene P (SMP mode) – more timings soon; Ranger (Linux IB cluster)
  - New distributed array features
  - New grow/shrink attached-set - in addition to existing subset capabilities

Experience at 220k..

- Lessons learnt
  - The scalable tree has really delivered!
    - More optimizations still possible
  - Even if you're quick, it's still all about the GUI
    - Present sensibly to the user – parallel stacks, data comparison
    - ... but some machines don't encourage full power of debugging due to their architecture
  - MPI spec probably never meant debuggers to scale!
    - Still linear things in there.. eg. MPIR_proctable
  - It's hard to debug a debugger without a debugger

Limits of the approach

- Logarithmic performance should last for many years
  - Any linear factors will eventually dominate
    - Must eradicate them all over time
    - Any memory usage on per-process basis
  - More intelligence can be pushed down the tree as need arises
  - Predict core operations on 1M or 10M cores will be under the pain threshold
  - SIMD/almost-SIMD GPUs fit within current approach (as threads, not individual processes)
- … but bugs can still be hard to find

Mind The Gap(s)

- Collaboration opportunity
  - No single organization has the resources to do everything
    - Plenty of opportunity for everyone in debugging
    - We use tools independently – but using together is more compelling
  - Examples:
    - MPI correctness checking – Marmot, Intel MPI Checker
    - Library specific sanity checkers for data
    - Comparative debugging
  - Ideal scenario: easy to prototype new bug finding ideas
    - Not tied to a particular product – but tied to an open API/scripting language
    - Single process or built from the top (drive a full debugger, or eg. combination of Wisconsin tools)

Questions?