Debugging at Scale

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Debugging at Scale

- At scale debugging - from 100 cores to 250,000
  - Problems faced by developers on real systems
  - Alternative approaches to debugging and how they stack up
  - How Allinea makes debugging at scale work

Allinea Software

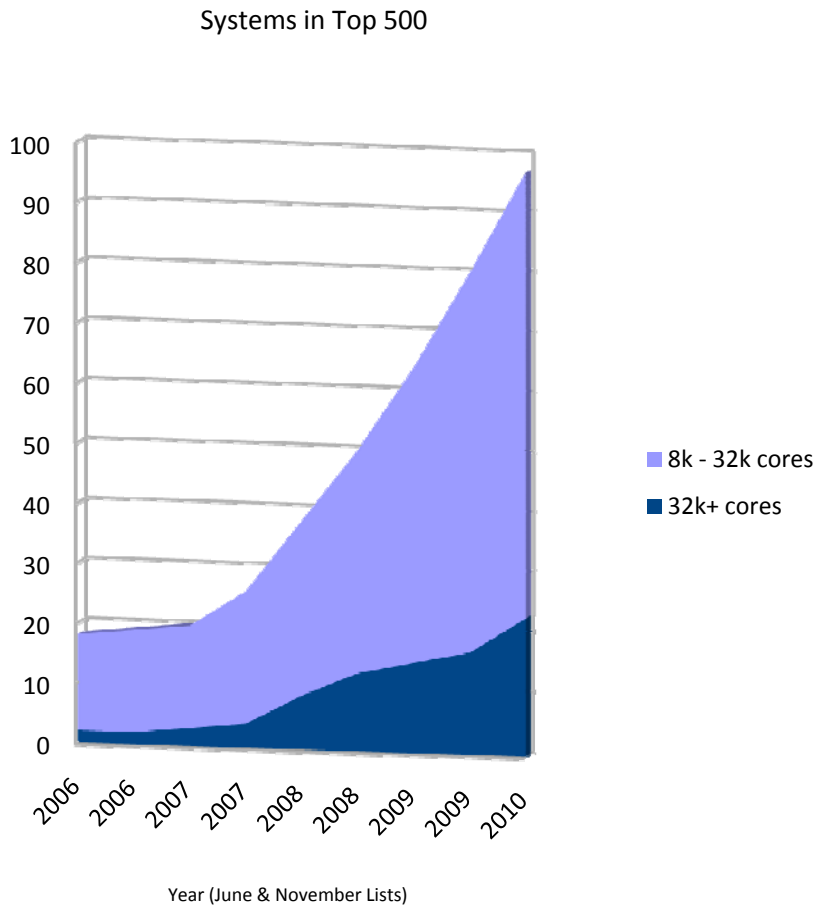
- HPC tools since 2001
  - Allinea DDT – Scalable parallel debugger
  - Allinea OPT – Optimisation tool for MPI and non-MPI
  - Allinea DDTLite – Parallel debugging plugin for Microsoft Visual Studio
- Large customer base
  - Ease of use – means tools get used
  - Users debugging regularly at all scales: 1 to 100,000 cores
  - World's only Petascale debugger

Some Clients and Partners

- Academic
  - Over 200 universities
- Major research centres
  - ANL, CEA, EPCC, GENCI, IDRIS, Juelich, NERSC, ORNL
- Aviation and Defence
  - Airbus, AWE, BAE, Dassault, DLR, EADS
- Energy
  - CGG Veritas, IFP, Total
- EDA
  - Cadence, Intel, Synopsys
- Climate and Weather
  - UK Met Office, Meteo France, NOAA

Background

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



Problems at Scale

- Increasing job sizes leads to unanticipated errors
  - Regular bugs
    - Data issues from larger data sets – eg. garbage in..., overflow
    - Logic issues and control flow
  - Increasing probability of independent random error
    - Memory errors/exhaustion – “random” bugs!
    - System problems – MPI and operating system
  - Pushing coded boundaries
    - Algorithmic (performance)
    - Hard-wired limits (“magic numbers”)
  - Unknown unknowns
    - ....

Strategies for bug fixing I

- Improved coding standards
  - Unit tests, assertions and consistency checks
    - Good practice – but tend to be single-process checks
    - Parallel checks also valid and good practice
  - Only checks for things you predict when developed
    - Coverage is rarely perfect
      - Unexpected problems – particularly random/system issues – often missed
    - Debugger still required
  - Combines well with debuggers
    - Find why a failure occurs not just a pass/fail

Strategies for bug fixing II

- Logging – printf and write
  - The oldest debugger still in active use
    - Tried and tested - as easy as “hello world”
    - If you have good intuition into the problem
      - Edit code, insert print, recompile and re-run
    - **Slow and iterative**
  - Use to log exceptions, progress or state
    - Post-mortem analysis only
      - Hard to establish real causal order of output of multiple processes
      - Output can be lost by process termination
    - Rapid growth in log output size
    - **Unscalable**

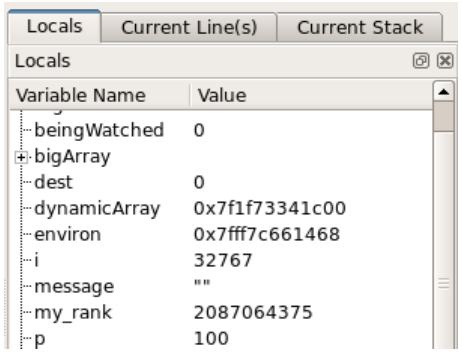
Strategies for bug fixing III

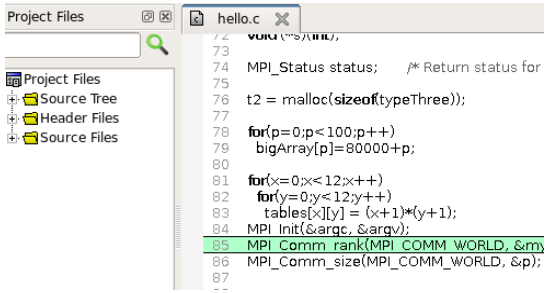
- Reproduce at a smaller scale
  - Attempt to make problem happen on fewer nodes
    - Often requires reduced data set – the large one may not fit
      - Didn't you already try the code at small scale?
      - Smaller data set may not trigger the problem
    - Does the bug even exist on smaller problems?
    - Is it a system issue – eg. an MPI problem?
  - Is probability stacking up against you?
    - **Example:** 1 in 10,000 independent probability of error?
    - Unlikely to spot on smaller runs – without many many runs
    - But near guaranteed to see it on a 10,000 core run
  - What can a parallel debugger do to help?
    - Debug at the scale of the problem. **Now**.

Use a Parallel Debugger

- 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?
  - Allinea DDT has changed the game

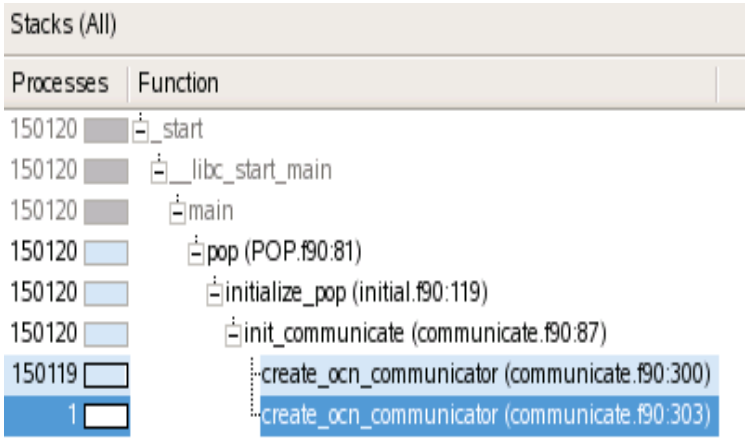
DDT in a nutshell



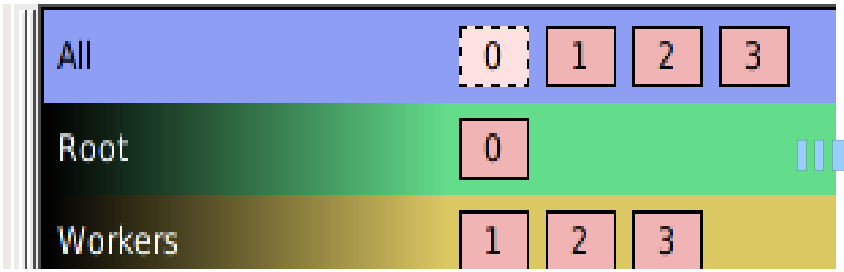


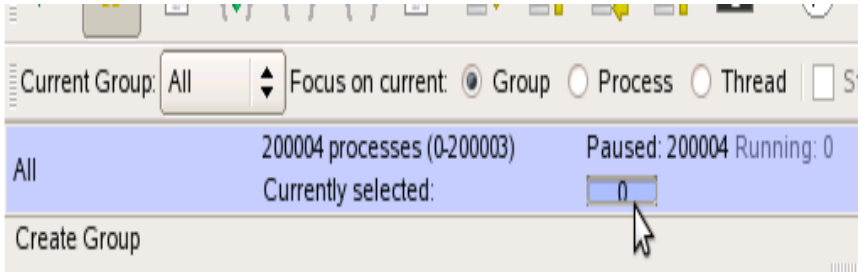
- Scalar features
  - Advanced C++ and STL
  - Fortran 90, 95 and 2003: modules, allocatable data, pointers, derived types
  - Memory debugging
- Multithreading & OpenMP features
  - Step, breakpoint etc. one or all threads
- MPI features
  - Easy to manage groups
  - Control processes by groups
  -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

Scalable Process Control

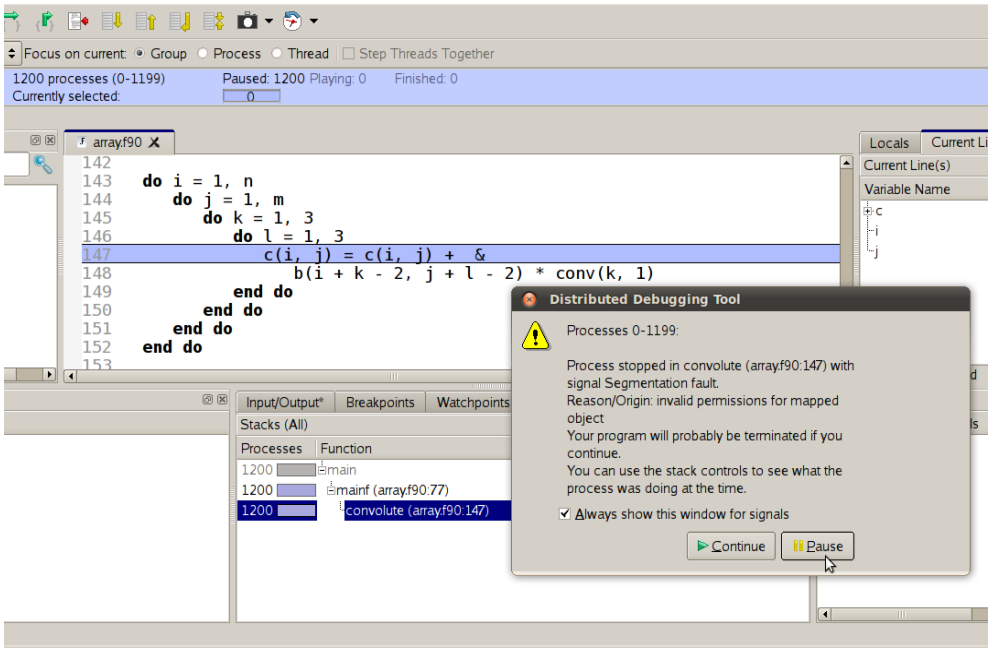


- Parallel Stack View
  - Find rogue processes quickly
  - Identify classes of process behaviour
  - Rapid grouping of processes
- Control Processes by Groups
  - Set breakpoints, step, play, stop for groups
  - Scalable groups view: compact group display





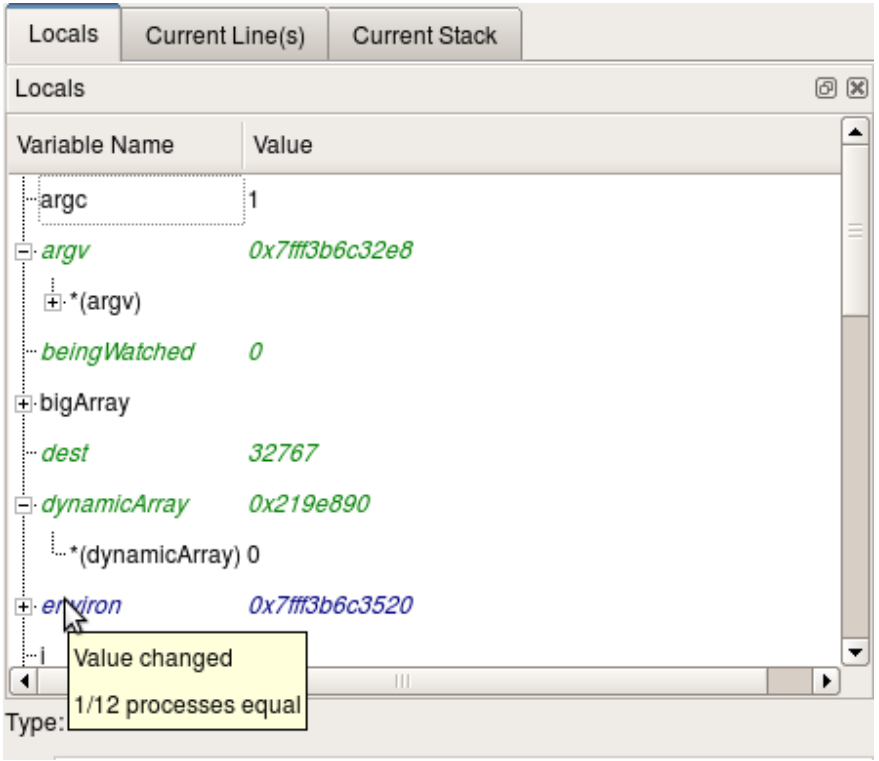
Handling Regular Bugs



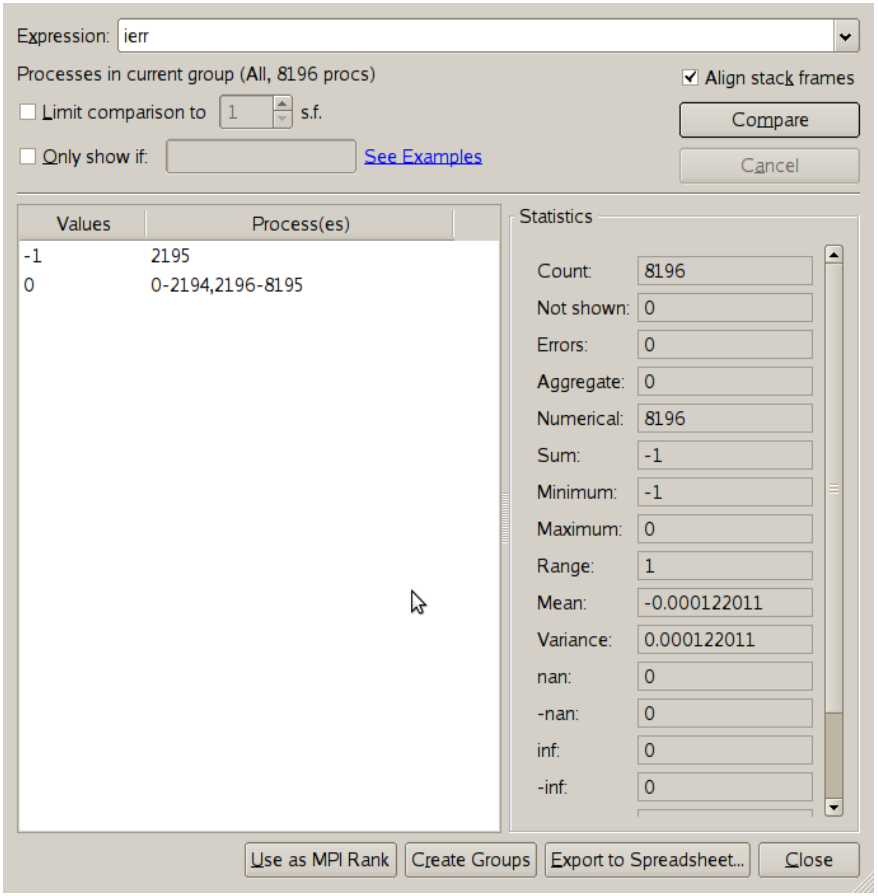
- Immediate stop on crash
  - Segmentation fault, or other memory problems
  - Abort, exit, error handlers
  - CUDA errors
- Scalable handling of error messages
- Leaps to the problem
  - Source code highlighted
  - Affected processes shown
  - Process stacks displayed clearly in parallel

Finding the cause

- Full class/structure browsing
  - Local variables and current line(s)
    - Show variables relevant to current position
    - Drag in the source code to see more
  - C, C++, F90: object members, static members, derived types
- Automatic comparison and change detection
  - Scalable and fast

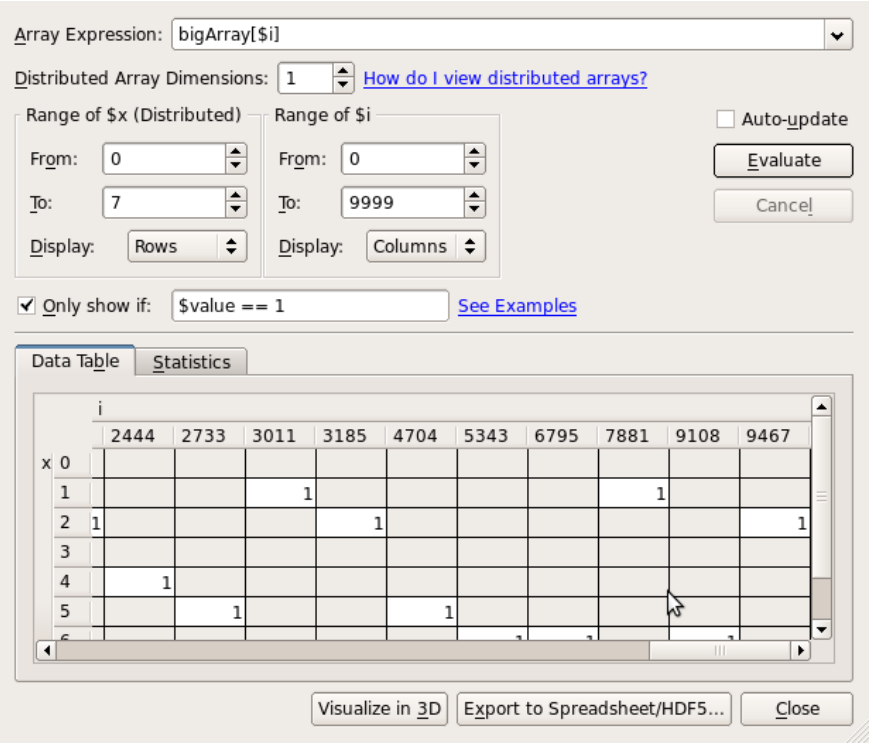


Finding rogue processes



- Easy to find where the differences are...
  - Cross process comparison of data
    - Fetches values from every process, compares and then groups by value
    - Summary of NaN, Inf and statistics
  - Easy to spot rogues
- Use to group processes
  - Define a process group and control en-masse

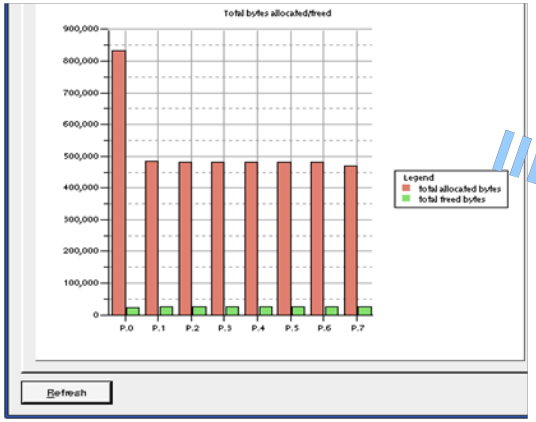
Large Array Support

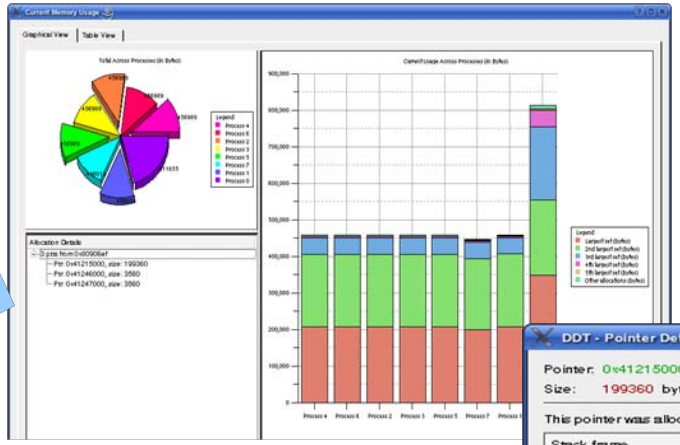


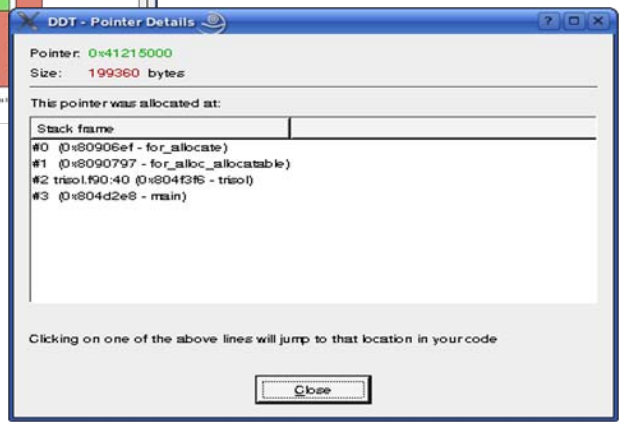
- Browse arrays
  - 1, 2, 3, … dimensions
  - Table view
- Filtering
  - Look for an outlying value
- Export
  - Save to a spreadsheet
- View arrays from multiple processes
  - Search terabytes for rogue data: in parallel with [v3.0]

Memory Debugging

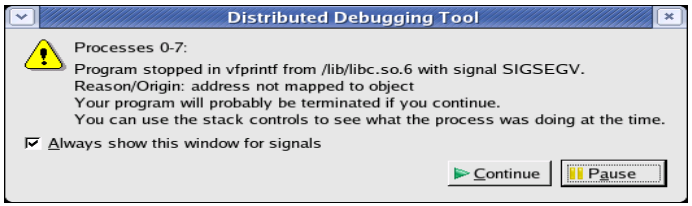
- Find memory leaks



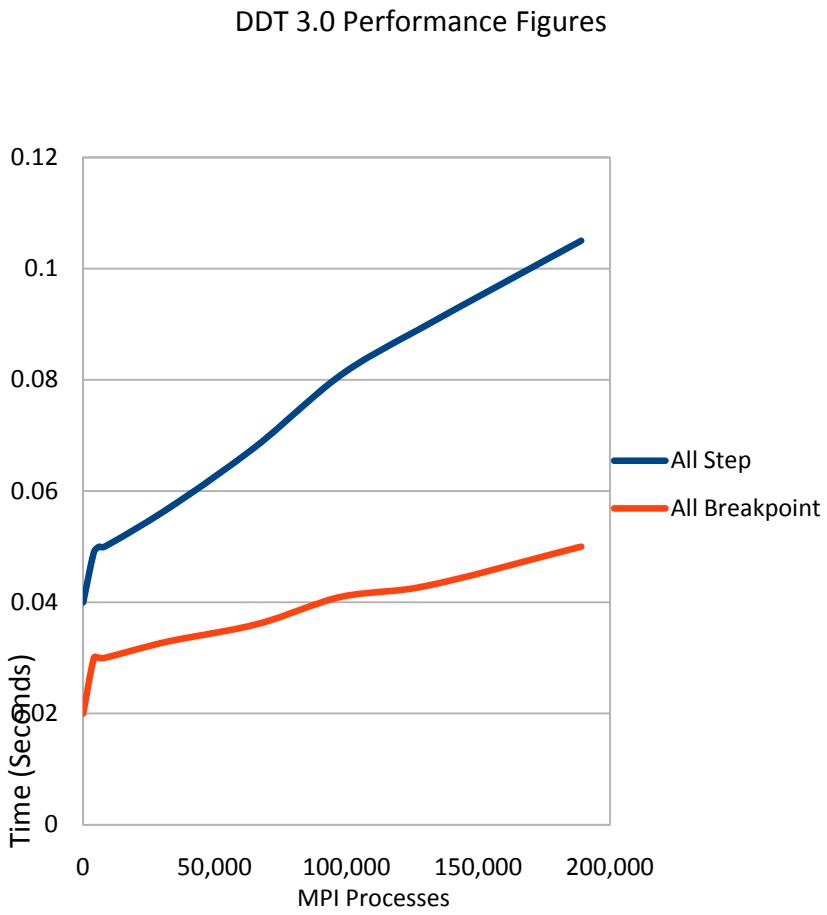




- Or stop on read/write beyond end of array:



DDT: Petascale Debugging



- DDT is delivering Petascale debugging **today**
  - Collaborations with ORNL on Jaguar Cray XT and CEA
  - 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

Summary

- Debuggers are recognised as the right tools to fix bugs quickly: other methods have limited success, and major issues at scale
- Debugging interfaces must scale to help the user understand what is happening
- Allinea DDT scales in performance and interface – breaking all records and making problems manageable
- See Allinea at Supercomputing 2010: Booth 2305

Questions?