Debugging in Heterogeneous Environments with TotalView

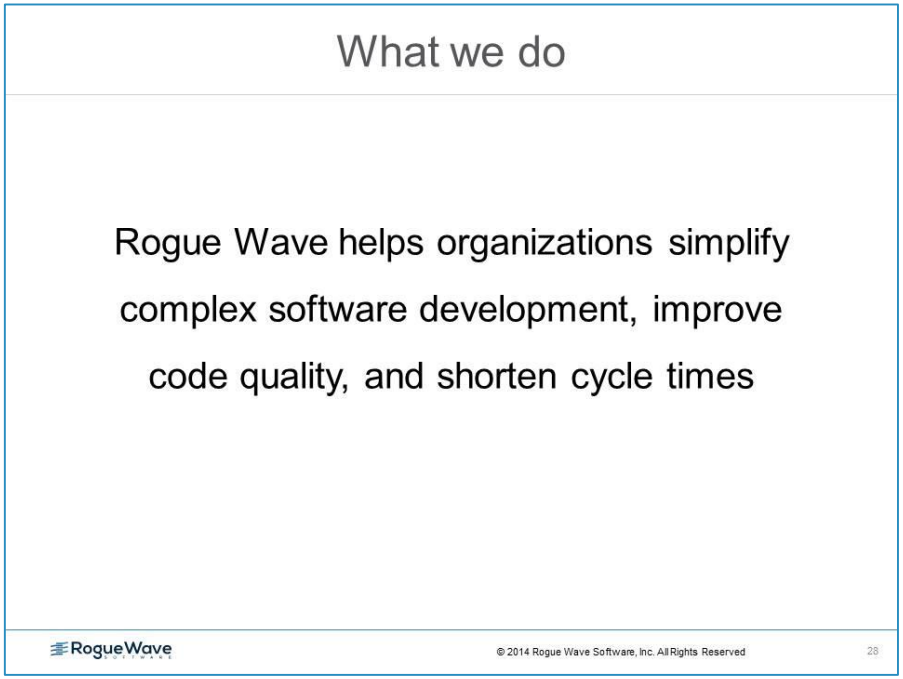
ECMWF HPC Workshop
30th October 2014

Agenda

- Introduction
- Challenges
- TotalView overview
- Advanced features
- Current work and future plans

Introduction

Rogue Wave



- History
  - Founded: 1989
  - Portfolio company of Audax Group
  - Acquisitions:
    - Visual Numerics: 2009
    - TotalView Technologies: 2010
    - ILOG Visualization for C++ : 2012
    - OpenLogic : 2013
    - Klocwork : 2013
    - ILOG Visualization for Java: 2014

- Customers
  - 3,000+ in 57 countries
  - Financial services, telecoms, oil and gas, government and aerospace, research and academic

- Global Locations
  - HQ: Boulder, CO
  - NA: Houston, TX; Corvallis, OR; Natick MA
  - EMEA: France, Germany, UK
  - APAC: Japan

Challenges of developing for heterogeneous environments

Challenges

- Number of CPU cores increasing but clock speed is static or decreasing
- How to program accelerators
  - Lower level languages (OpenCL, CUDA)
  - Directives based (OpenACC, OpenMP)
- New algorithms or programming models may be needed
- Data sizes increasing exponentially
- Memory is increasingly important
- Power consumption and constraints

How does Rogue Wave help?

TotalView debugger

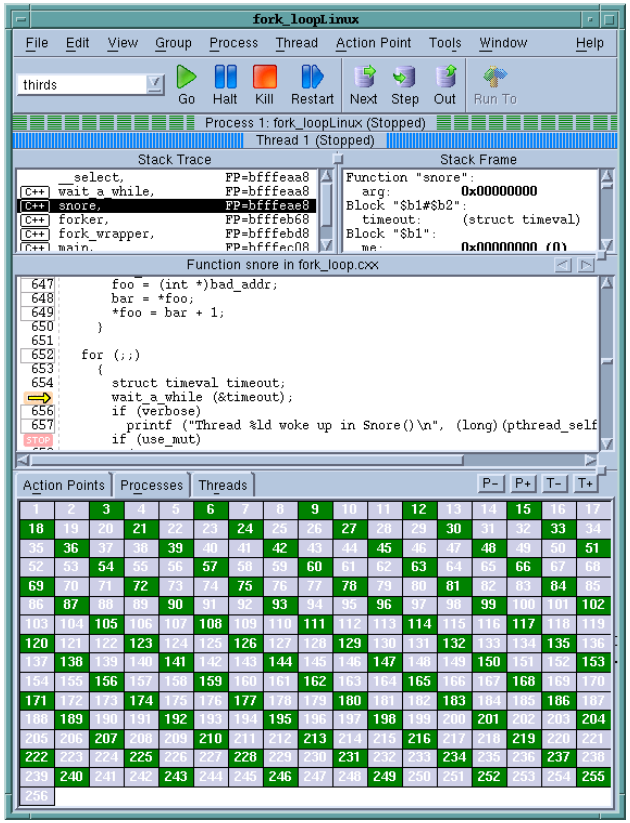
- Troubleshooting and analysis tool
  - Visibility into applications
  - Control over applications
- Scalability
- Usability
- Support for HPC platforms and languages

TotalView Overview

What is TotalView®?

Application Analysis and Debugging Tool: Code Confidently

- Debug and Analyse C/C++ and Fortran on Linux™, Unix or Mac OS X
- Laptops to supercomputers
- Makes developing, maintaining, and supporting critical apps easier and less risky



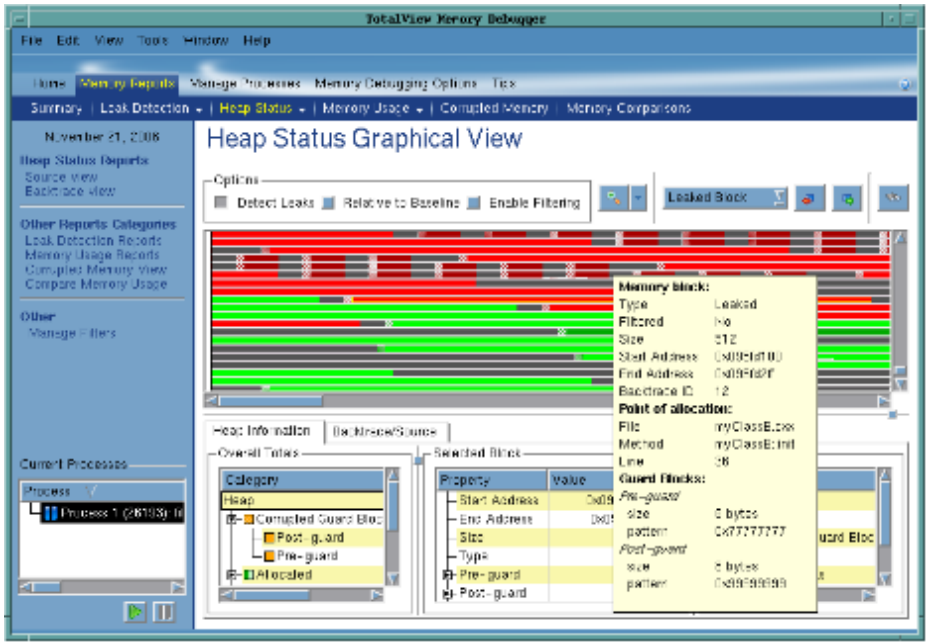
Major Features

- Easy to learn graphical user interface with data visualization
- Parallel Debugging
  - MPI, Pthreads, OpenMP™
  - CUDA™, OpenACC®, and Intel® Xeon Phi™ coprocessor
- Low tool overhead resource usage
- Includes a Remote Display Client which frees you to work from anywhere
- Memory Debugging with MemoryScape™
- Deterministic Replay Capability Included on Linux/x86-64
- Non-interactive Batch Debugging with TVScript and the CLI
- TTF & C++View to transform user defined objects

MemoryScape®

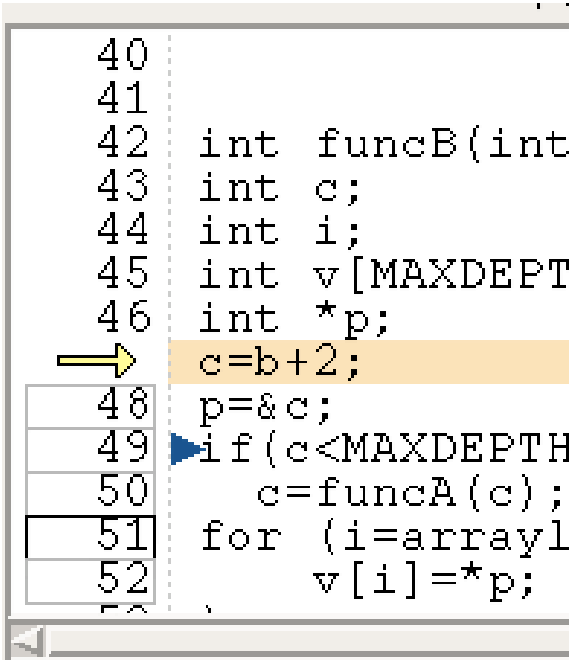
- Runtime Memory Analysis : Eliminate Memory Errors
  - Detects memory leaks *before* they are a problem
  - Explore heap memory usage with powerful analytical tools
  - Use for validation as part of a quality software development process

- Major Features
  - Included in TotalView, or Standalone
  - Detects
    - Malloc API misuse
    - Memory leaks
    - Buffer overflows
  - Supports
    - C, C++, Fortran
    - Linux, Unix, and Mac OS X
    - Intel® Xeon Phi™
    - MPI, pthreads, OMP, and remote apps
  - Low runtime overhead
  - Easy to use
    - Works with vendor libraries
    - No recompilation or instrumentation



Deterministic Replay Debugging

- Reverse Debugging: Radically simplify your debugging
  - Captures and Deterministically Replays Execution
    - Not just “checkpoint and restart”
  - Eliminate the Restart Cycle and Hard-to-Reproduce Bugs
  - Step Back and Forward by Function, Line, or Instruction



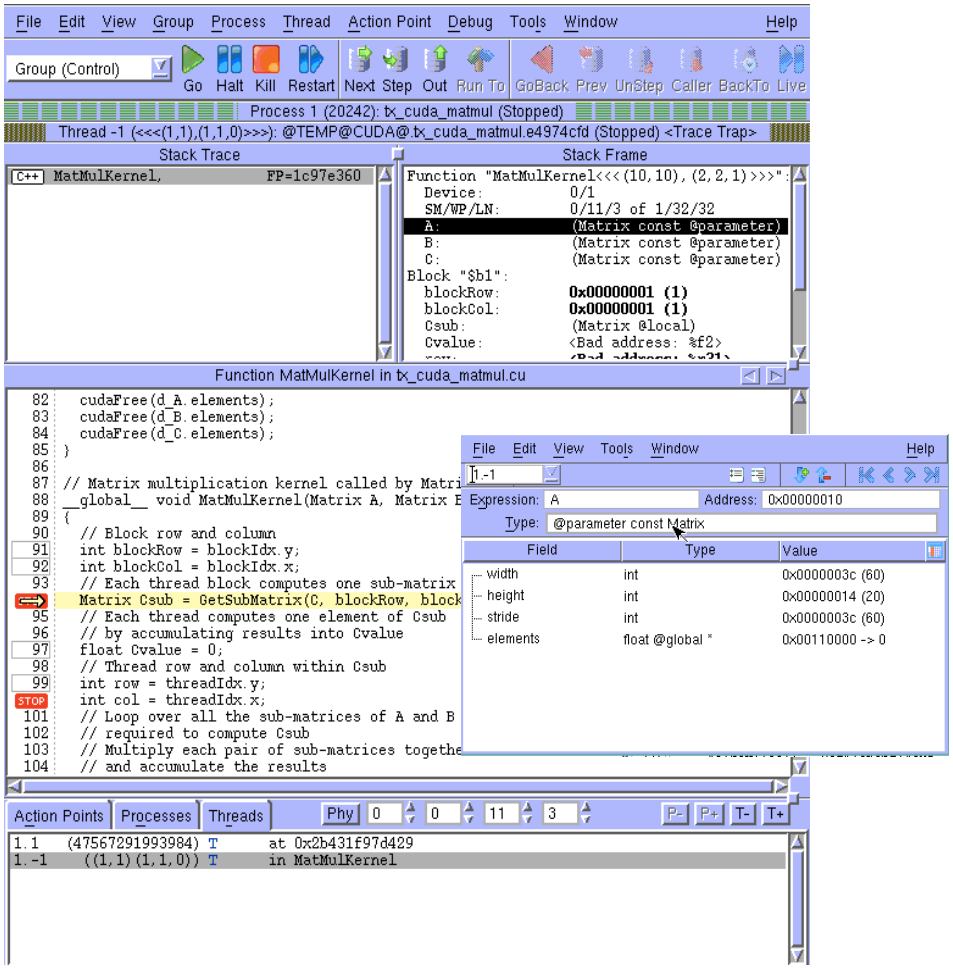
- Specifications
  - A feature included in TotalView on Linux x86 and x86-64
    - No recompilation or instrumentation
    - Explore data and state in the past just like in a live process, including C++View transformations
  - Replay on Demand: enable it when you want it
  - Supports MPI on Ethernet, Infiniband, Cray XE Gemini
  - Supports Pthreads, and OpenMP
  - New: Save / Load Replay Information (CLI only)

Cambridge Study

UNIVERSITY OF CAMBRIDGE
Judge Business School

- Survey conducted by the Judge Business School at Cambridge University concluded that Reverse Debuggers allow users, on average, to spend 13% less of their programming time debugging.
  - Programming was 50% of total work week on average
  - Debugging was 50% of programming time without reverse debugging
  - Debugging was 37% of programming time with reverse debugging
  - That frees up 130 hours (>3 work weeks, 6.5% total time) per developer per year for design and new feature development
- The survey looked at total value (salaries & overhead) of debugging as a task and they determined that this savings could, across the whole world economy, be work $41 billion in increased productivity.
  - The productivity improvement should be worth $2,500 per developer per year (salary only) or $5,000 per year with overhead.
- http://www.roguewave.com/company/news-events/press-releases/2013/university-of-cambridge-reverse-debugging-study.aspx

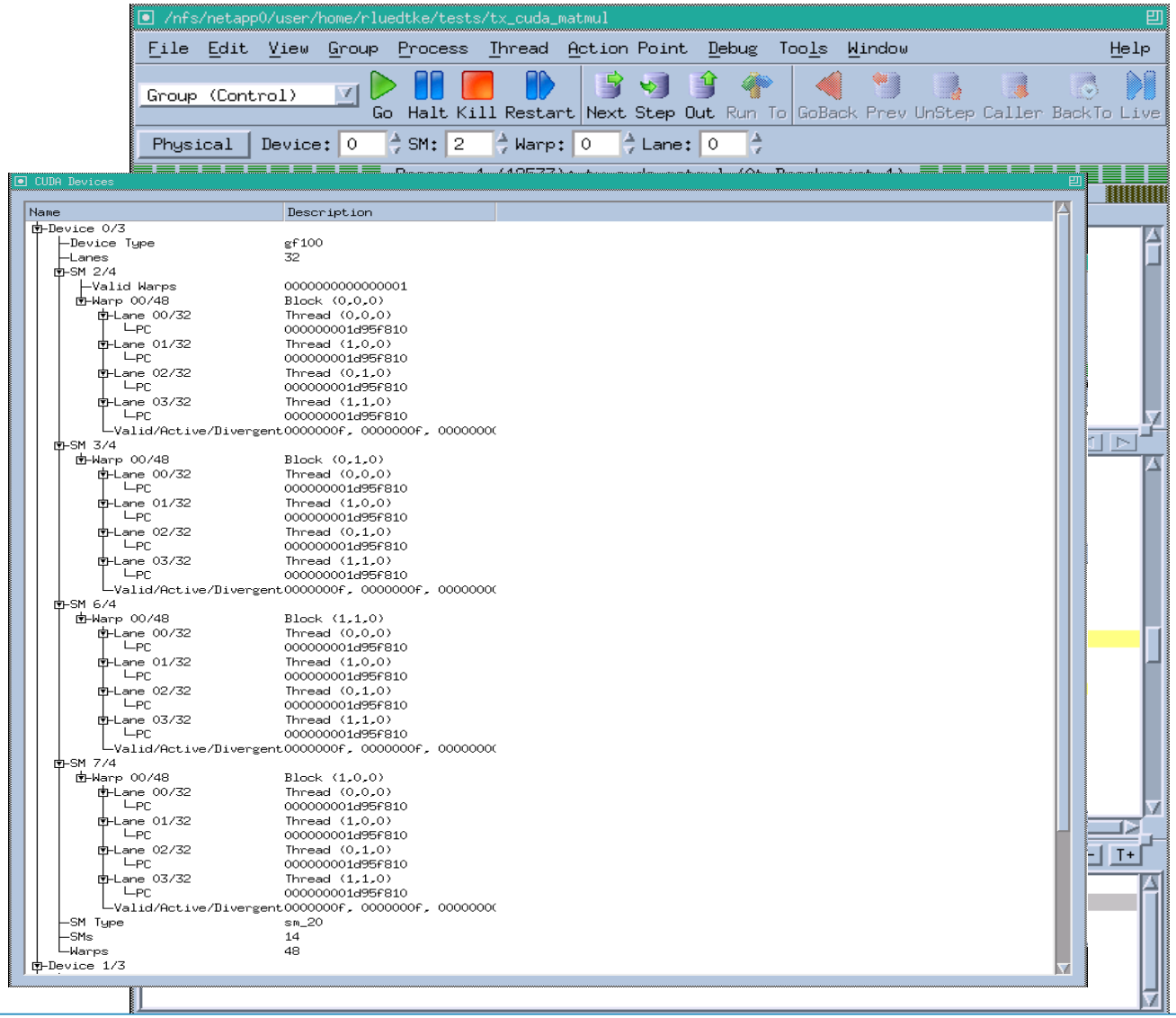
TotalView for the NVIDIA ® GPU Accelerator



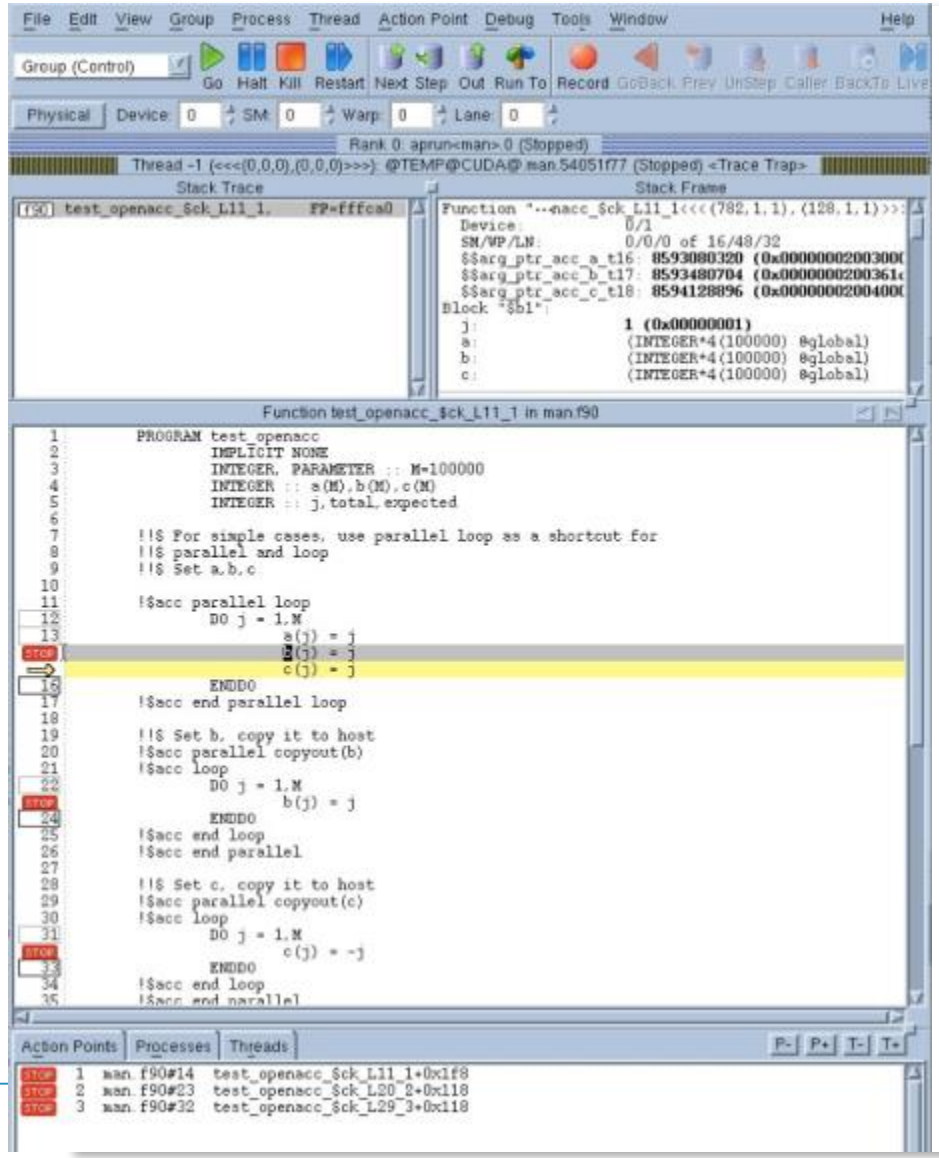
- NVIDIA CUDA 6.5
  - With support for Unified Memory
- Features and capabilities include
  - Support for dynamic parallelism
  - Support for MPI based clusters and multi-card configurations
  - Flexible Display and Navigation on the CUDA device
    - Physical (device, SM, Warp, Lane)
    - Logical (Grid, Block) tuples
  - CUDA device window reveals what is running where
  - Support for types and separate memory address spaces
  - Leverages CUDA memcheck

RogueWave SOFTWARE

Displaying NVIDIA GPU Device Information



TotalView for OpenACC



OpenACC®

DIRECTIVES FOR ACCELERATORS

- Step host & device
- View variables
- Set breakpoints

Compatibility with Cray CCE 8 OpenACC

TotalView for the Intel® Xeon Phi™ coprocessor

Supports All Major Intel Xeon Phi Coprocessor Configurations

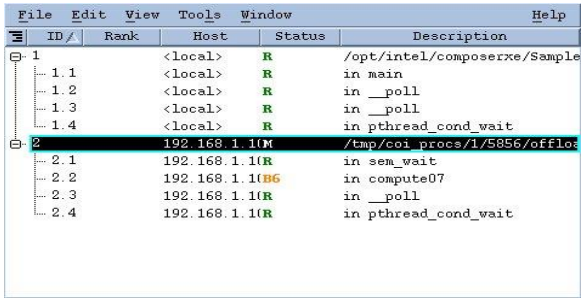
- Native Mode
  - With or without MPI
- Offload Directives
  - Incremental adoption, similar to GPU
- Symmetric Mode
  - Host and Coprocessor
- Multi-device, Multi-node
- Clusters

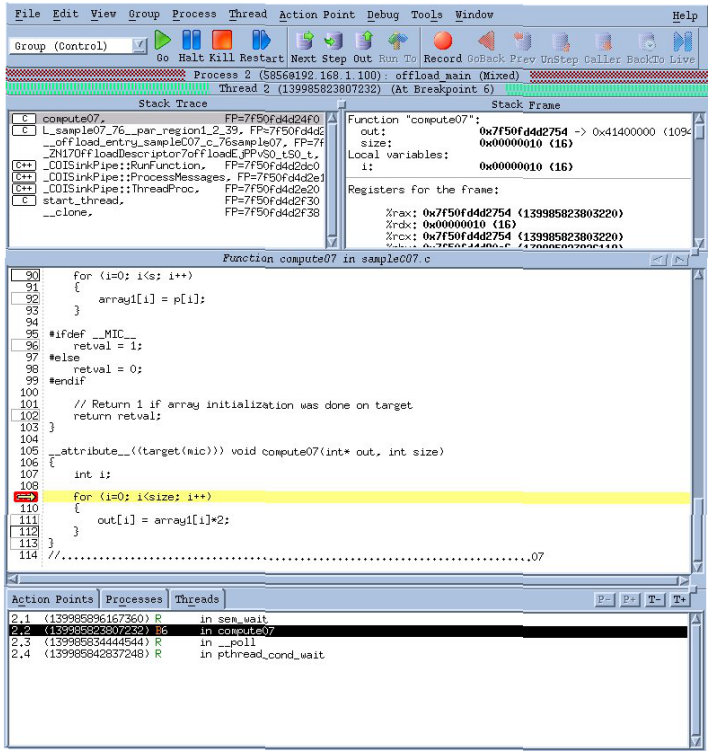
User Interface

- MPI Debugging Features
  - Process Control, View Across, Shared Breakpoints
- Heterogeneous Debugging
  - Debug Both Xeon and Intel Xeon Phi Processes

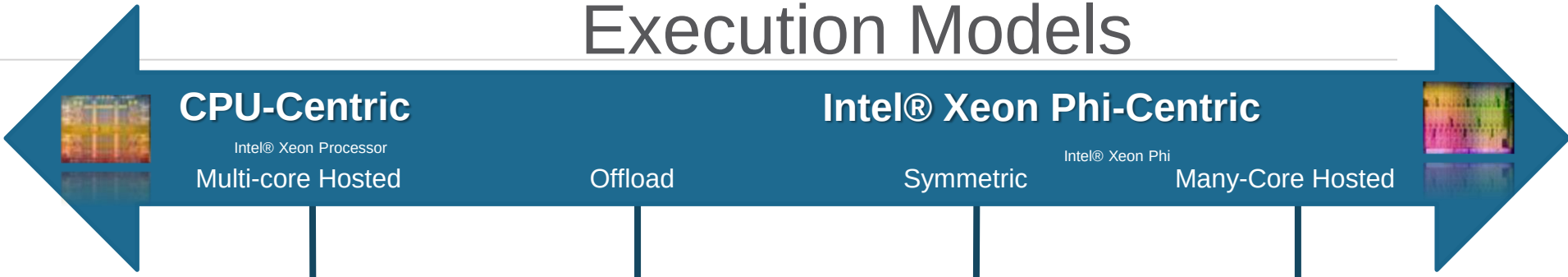
Memory Debugging

- Both native and symmetric mode





Spectrum of Intel Xeon Phi Execution Models



General purpose serial and parallel computing

Codes with highly- parallel phases

Codes with balanced needs

Highly-parallel codes

Main( ) Foo( ) MPI_*()	***Main( ) Foo( ) MPI_*()***	***Main( ) Foo( ) MPI_*()***	
	Foo( )	***Main( ) Foo( ) MPI_*()***	***Main() Foo( ) MPI_*()***

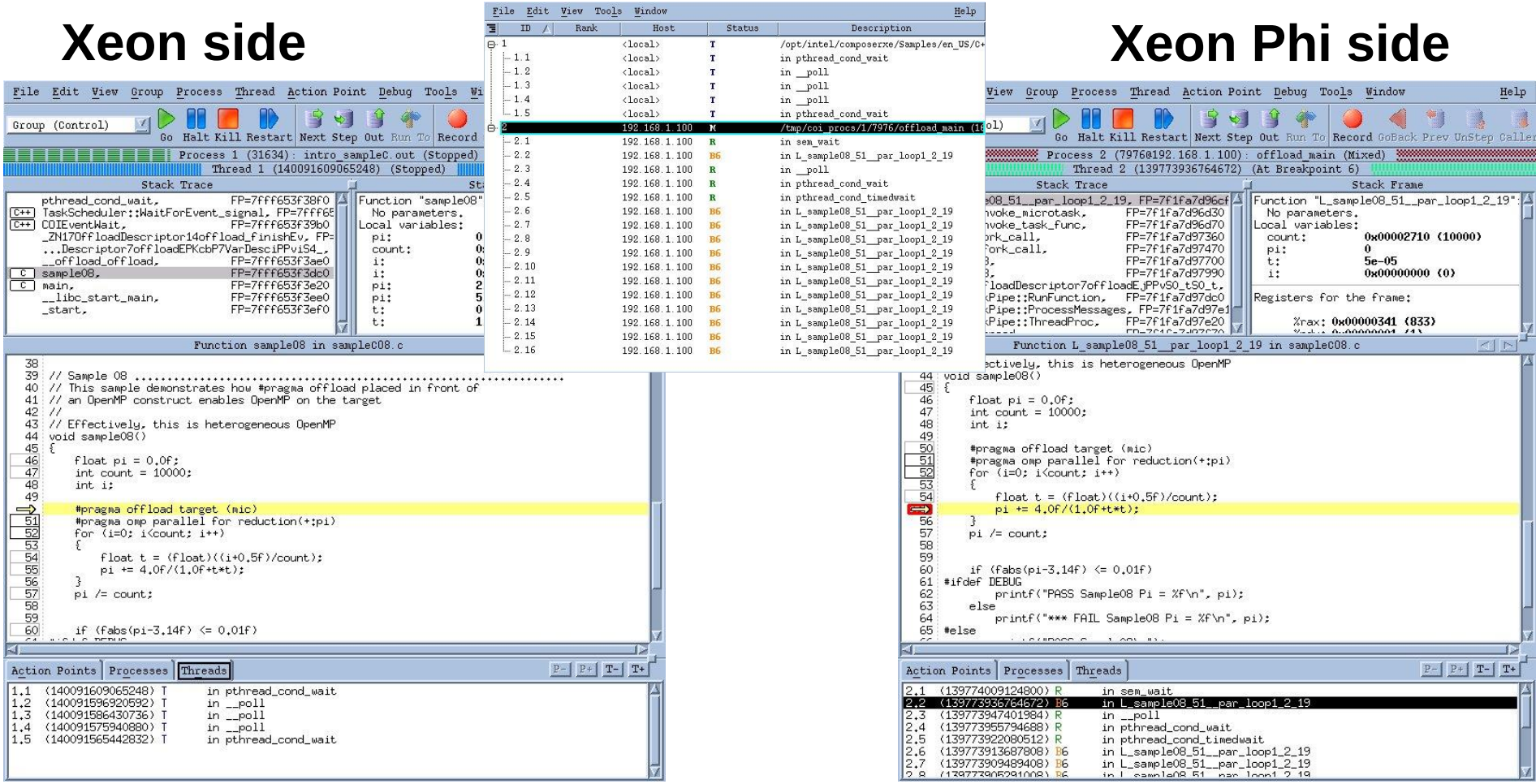
PCIe

Productive Programming Models Across the Spectrum

Debugging Intel Xeon Phi Applications with Offloaded Code

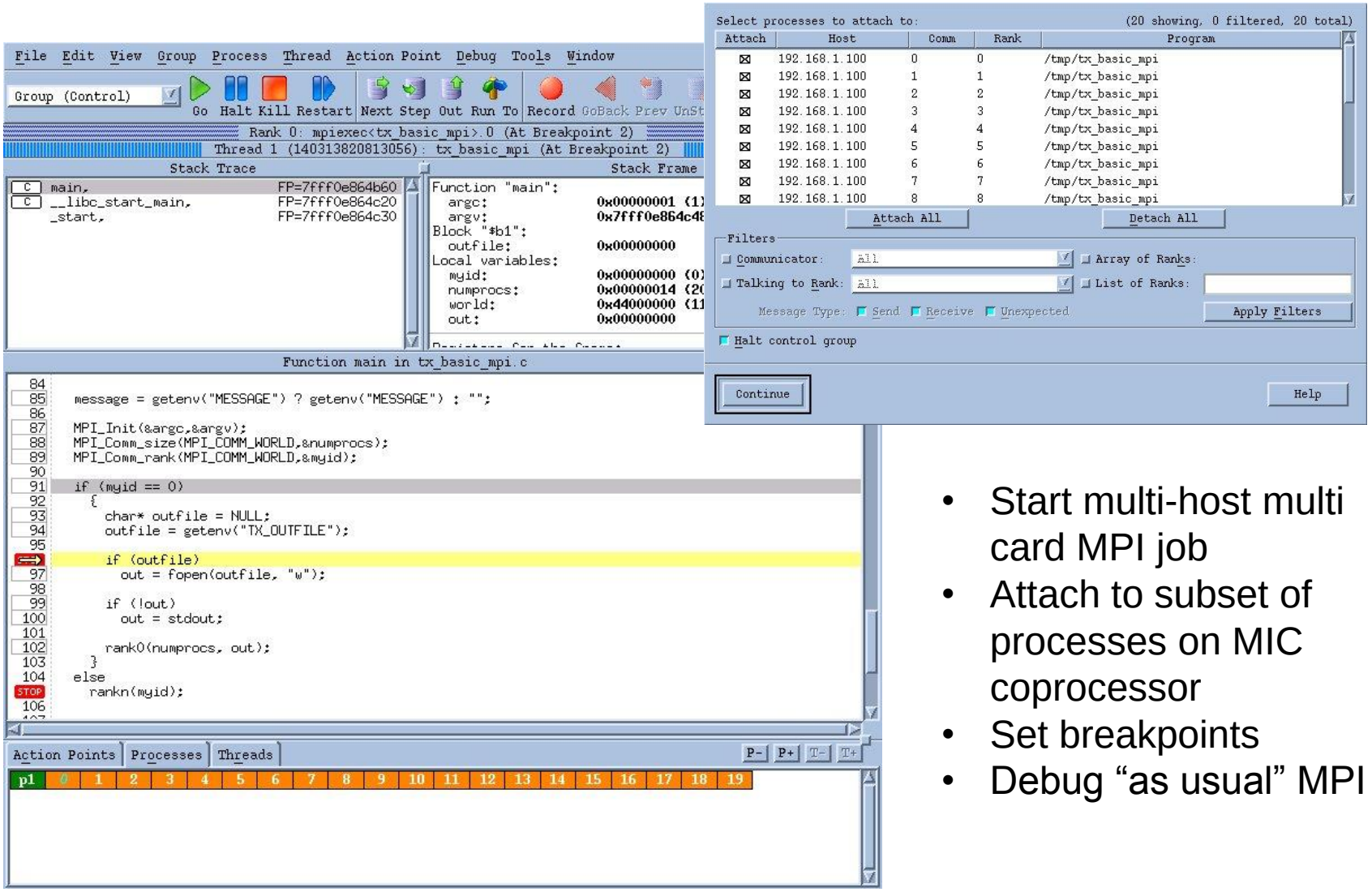
Xeon side

Xeon Phi side



One debugging session for MIC-accelerated code

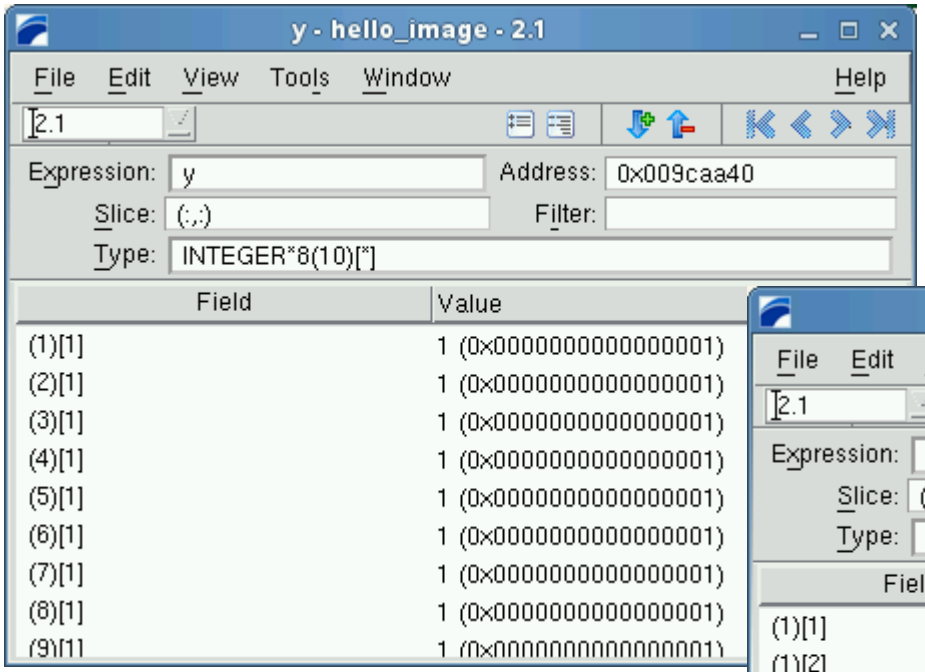
Debugging Intel Xeon Phi MPI Applications



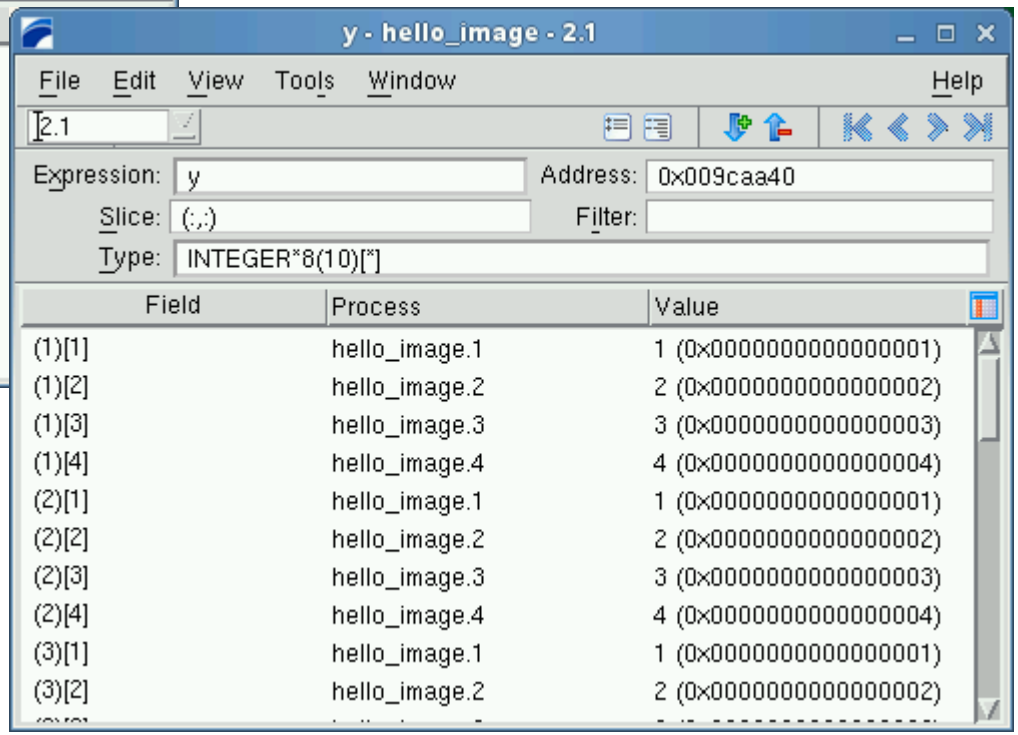
- Start multi-host multi card MPI job
- Attach to subset of processes on MIC coprocessor
- Set breakpoints
- Debug “as usual” MPI

Coarray Fortran

Diving on CAF array y



Diving on CAF array y across processes

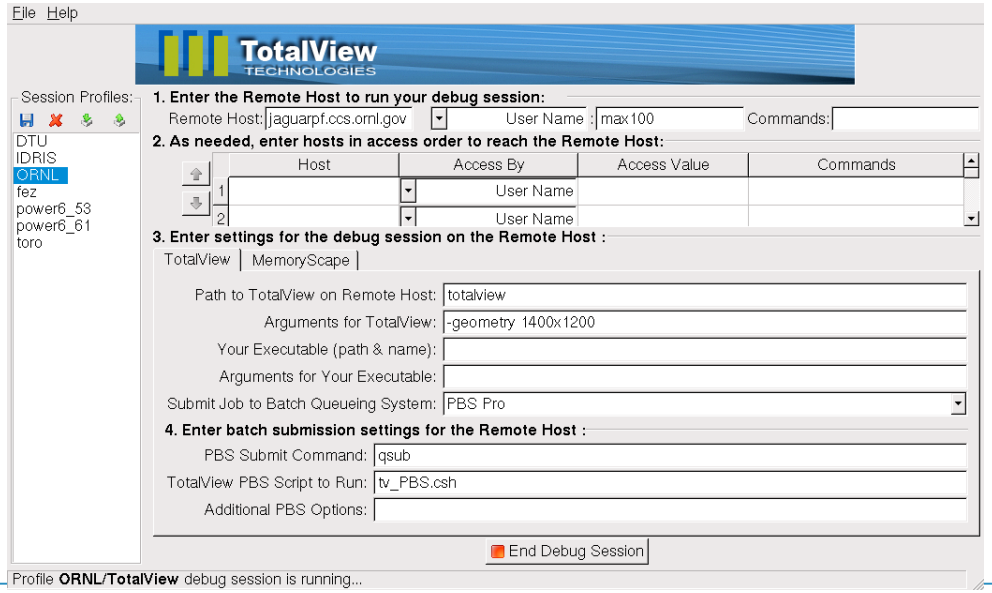


Supported on Cray platforms with CCE

Advanced Features

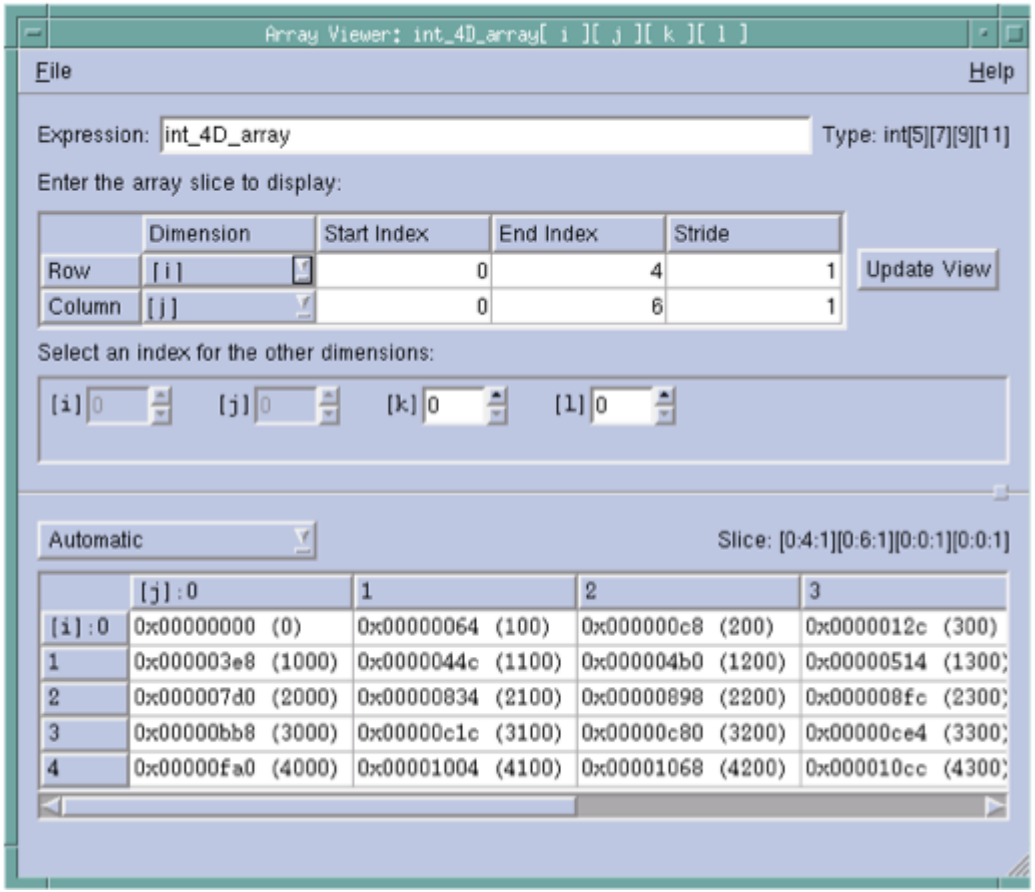
Remote Display Client

- Offers users the ability to easily set up and operate a TotalView debug session that is running on another system
- Consists of two components
  - Client – runs on local machine
  - Server – runs on any system supported by TotalView and “invisibly” manages the secure connection between host and client
- Remote Display Client is available for:
  - Linux x86, x86-64
  - Windows XP, Vista, 7
  - Mac OS X

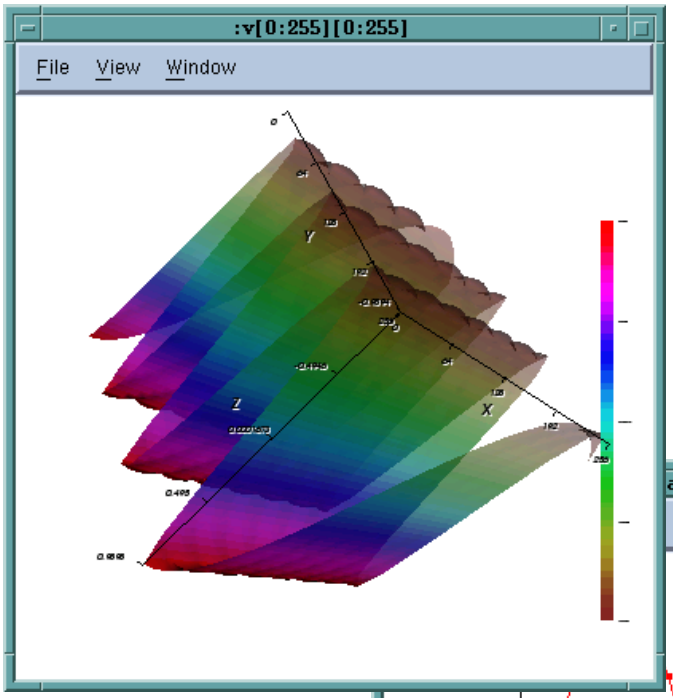


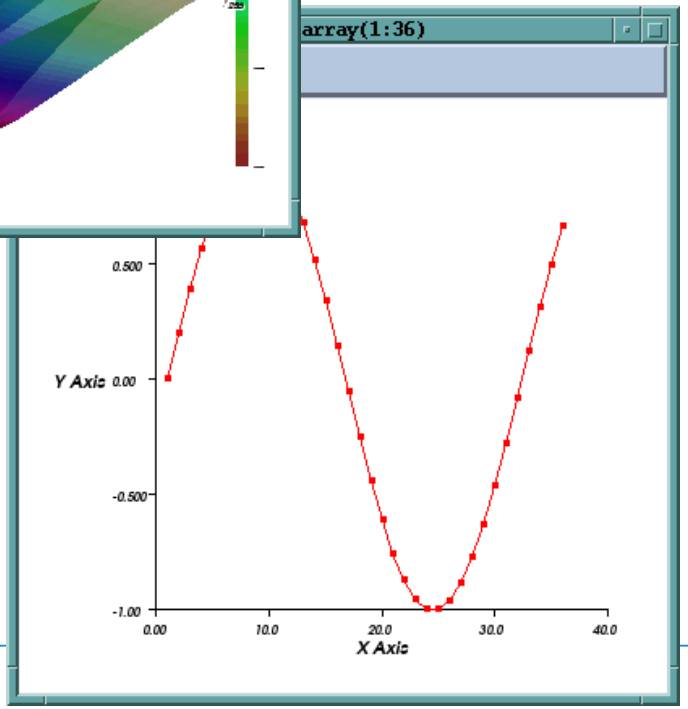
Multi-dimensional array viewer

- See your arrays on a Grid display
- 2-D, 3-D, …N-D
- Arbitrary slices
- Specify data representation
- Windowed data access – Fast



Visualizing Arrays



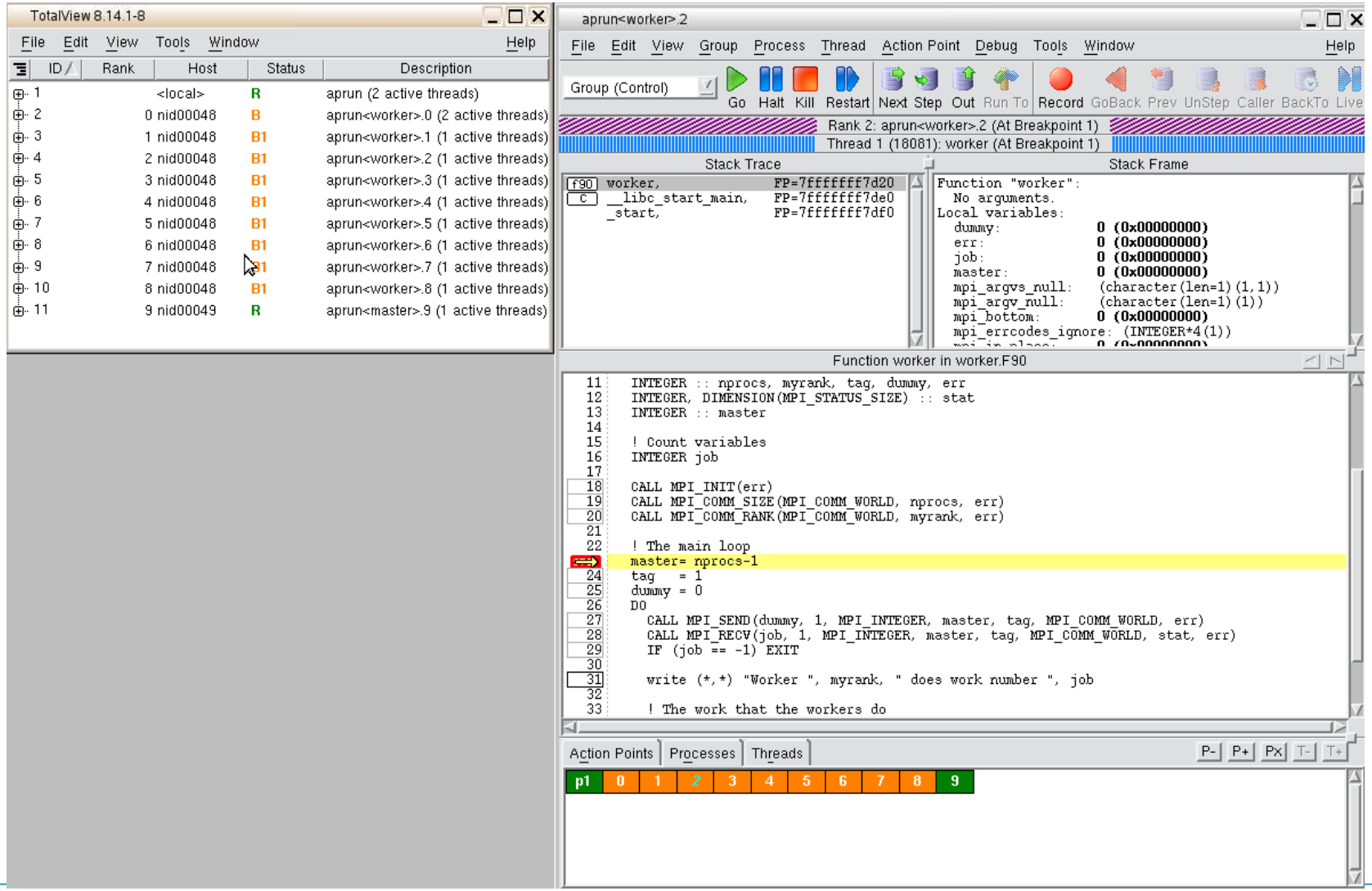


- Visualize array data using Tools > Visualize from the Variable Window
- Large arrays can be sliced down to a reasonable size first
- Visualize is a standalone program
- Data can be piped out to other visualization tools

- Visualize allows to spin, zoom, etc.
- Data is not updated with Variable Window; You must revisualize
- $visualize() is a directive in the expression system, and can be used in evaluation point expressions.

Debugging MPMD applications

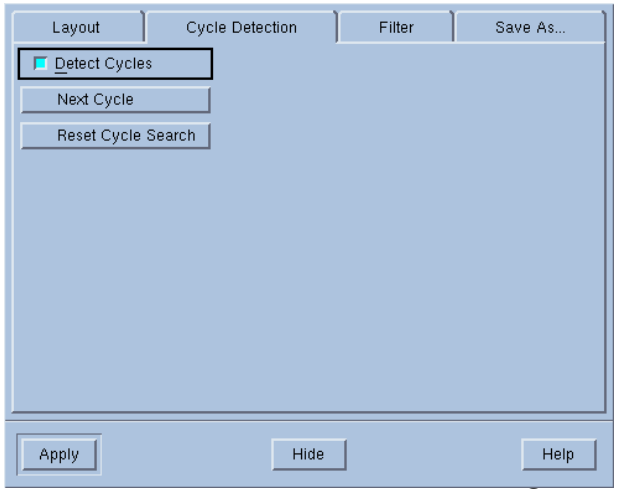
totalview -args aprun -n 9 worker : -n 1 master

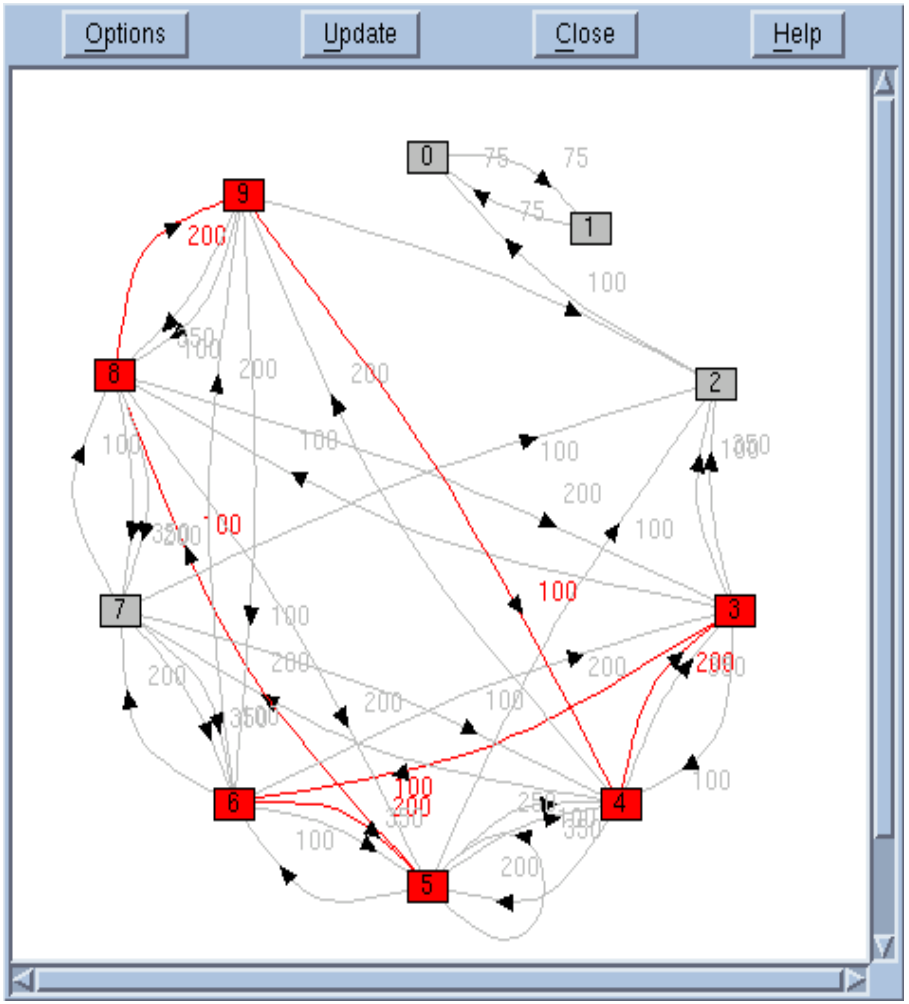


Message Queue Graph

Message Queue Debugging

- **Filtering**
  - Tags
  - MPI Communicators
- **Cycle detection**
  - Find deadlocks



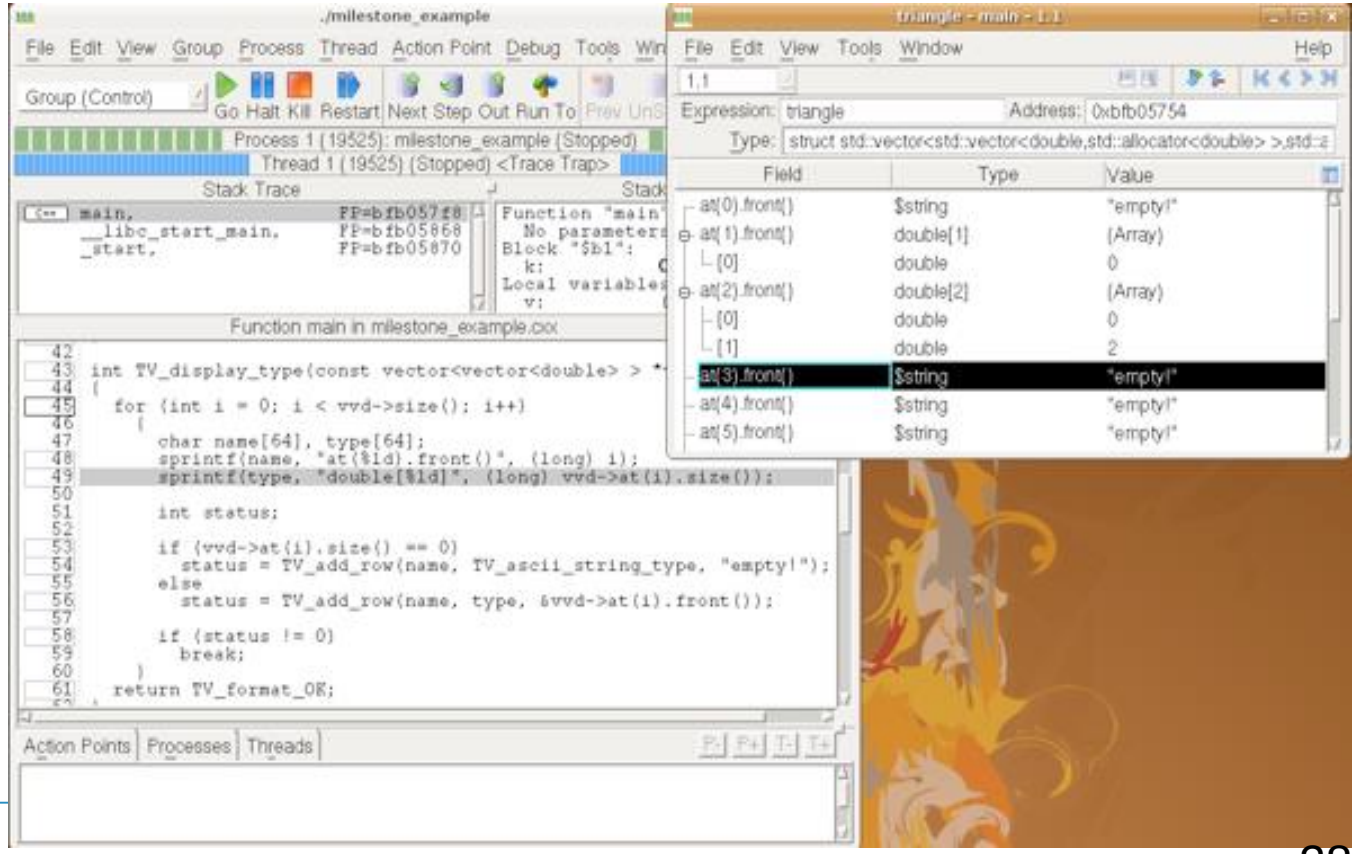


TVScript

- Gives you non-interactive access to TotalView's capabilities
- Useful for
  - Debugging in batch environments
  - Watching for intermittent faults
  - Parametric studies
  - Automated testing and validation
- TVScript is a script (not a scripting language)
  - It runs your program to completion and performs debugger actions on it as you request
  - Results are written to an output file
  - No GUI
  - No interactive command line prompt
- Used at sites such as DMI and STFC Daresbury for automated comparative debugging

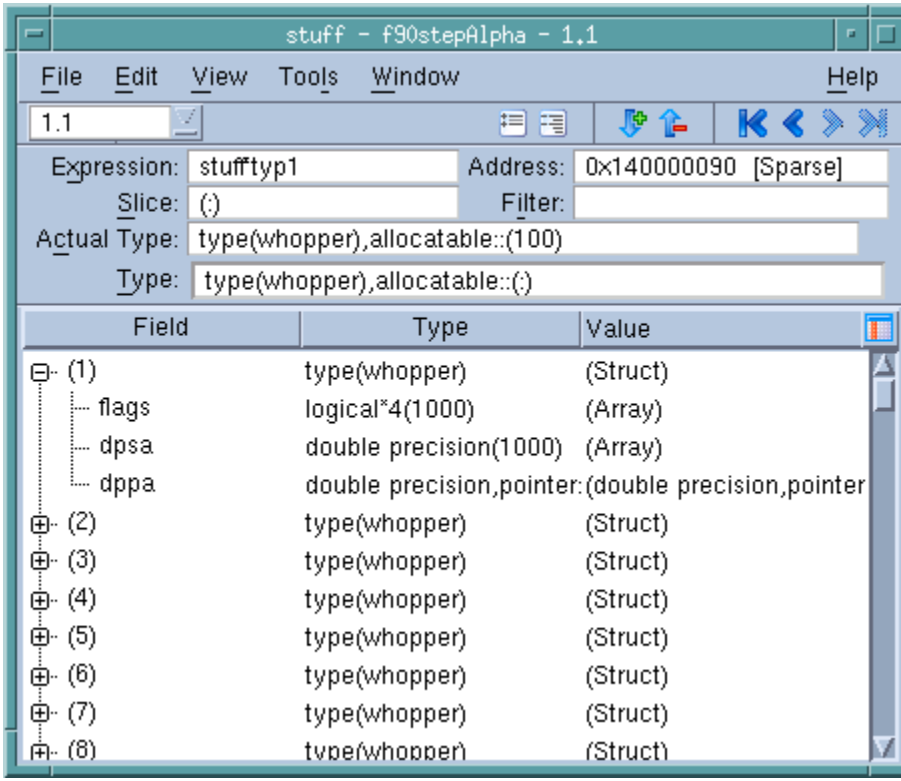
C++View

- C++View is a simple way for you to define type transformations
  - Simplify complex data
  - Aggregate and summarize
  - Check validity
- Transforms
  - Type-based
  - Compose-able
  - Automatically visible
- Code
  - C++
  - Easy to write
  - Resides in target
  - Only called by TotalView



Viewing Fortran User-Defined Types

```
TYPE WHOPPER
    LOGICAL, DIMENSION(ISIZE) :: FLAGS
    DOUBLE PRECISION, DIMENSION(ISIZE) :: DPSA
    DOUBLE PRECISION, DIMENSION(:), POINTER :: DPPA
    END TYPE WHOPPER
TYPE(WHOPPER), DIMENSION(:), ALLOCATABLE :: STUFFTYP1
```



Current Work and Future Plans

What is new in TotalView 8.14.1

- CUDA 6.5 support
- Coarray Fortran support for the Cray CCE compiler
- Extended support for type transformations with the Intel compiler (unordered STL collection classes)
- Improved delayed symbol processing (better performance for larger executables)

Multi-phase R&D Projects Underway

- Massive Scalability
  - Collaboration with LLNL and Tri-lab partners
  - Targeting Cray, Blue Gene and Linux Clusters
  - MRNet software overlay network for multicast and reduction
- New GUI
  - Sleek, Modern and Fast
  - Configurable
  - Improved Usability
  - Provides aggregation capabilities for big data and scale
  - Leveraging math and stat expertise from IMSL
- Working with customers through early access programs
  - Customer input is key to the success of both programs

Thanks!

- Visit the website
  - http://www.roguewave.com/products/totalview.aspx
  - Videos (3 new videos on Xeon Phi)
  - Documentation
  - Sign up for an evaluation
- Visit us at SC14 (booth 2338)

hpc matters.