TotalView Training

DECEMBER 2020

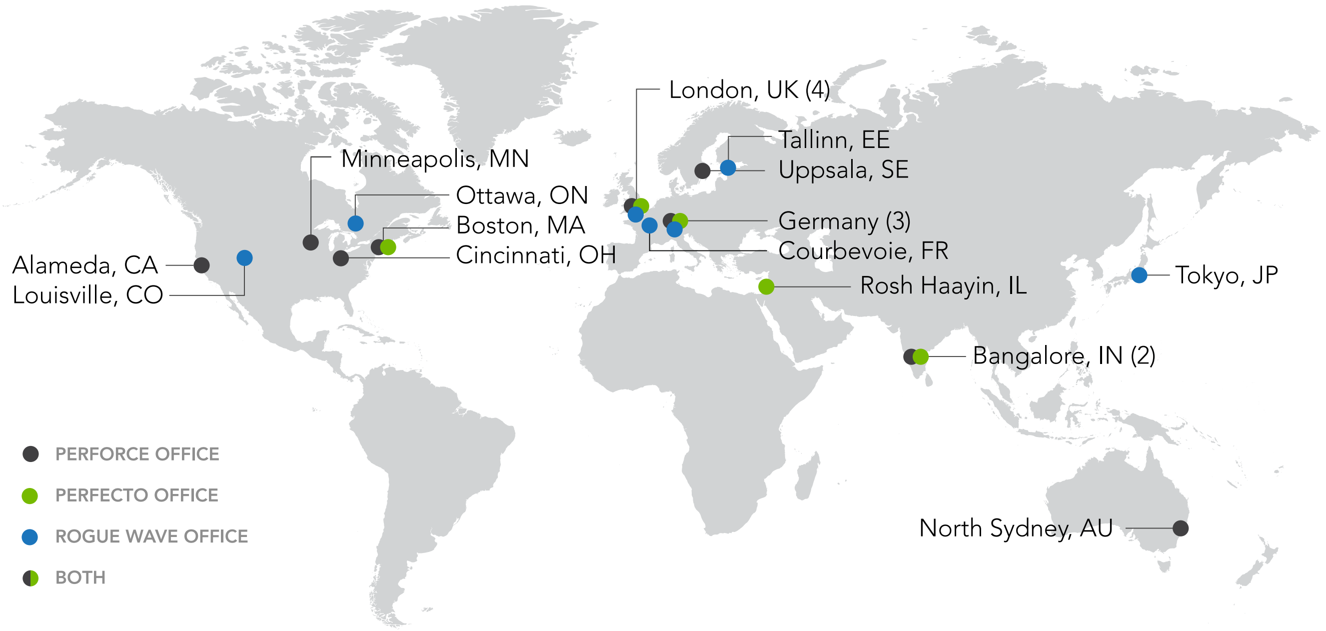
LBL/NERSC Agenda

- Introduction (Bill)
- Overview of TotalView Labs (Bill/Dean)
- TotalView Features (Bill)
- TotalView’s New UI (Dean)
- Remote Debugging – Remote Display Client (Dean)
- Remote Debugging – Remote UI with Reverse Connect Feature (Bill)
- Startup (Dean)
- UI Navigation and Process Control (Dean)
- Action Points (Dean)
- Examining and Editing Data (Dean)
- Advanced C++ and Data Debugging (Dean)
- Q&A
- ***Break***
- Python Debugging (Dean)
- Replay Engine (Dean)
- OpenMP debugging (Bill)
- MPI Debugging (Bill)
- MemoryScape (Dean or Bill)
- CUDA debugging (Bill)
- TotalView Roadmap (Bill)
- Common TotalView usage hints
- Q&A
- TotalView Labs Help

Introduction

Perforce Global Footprint

- Customers in 80 countries.
- ~9,000 customers worldwide.
- More than 250 of the Fortune 500.
- Customers deploying multiple products.
- 25+ offices and 4 data centers which give us global reach.
- Over 900 employees in 25 countries.



Perforce Product Portfolio

Agile Management	Code Management & Collaboration	Application Mgmt. & Components	Automated Testing
Helix ALM	Helix Core	Akana	Helix QAC
Hansoft	Helix4Git	OpenLogic	Perfecto
Gliffy	JRebel	Zend	Klocwork
	TotalView	Visualization	
		SourcePro	
		IMSL	

Overview of TotalView Labs

Overview of TotalView Labs

Nine different labs and accompanying example programs

- Lab 1 - Debugger Basics: Startup, Basic Process Control, and Navigation
- Lab 2 - Viewing, Examining, Watching, and Editing Data
- Lab 3 - Examining and Controlling a Parallel Application
- Lab 4 - Exploring Heap Memory in an MPI Application
- Lab 5 - Debugging Memory Comparisons and Heap Baseline *
- Lab 6 - Memory Corruption discovery using Red Zones *
- Lab 7 - Batch Mode Debugging with TVScript
- Lab 8 - Reverse Debugging with ReplayEngine
- Lab 9 - Asynchronous Control Lab

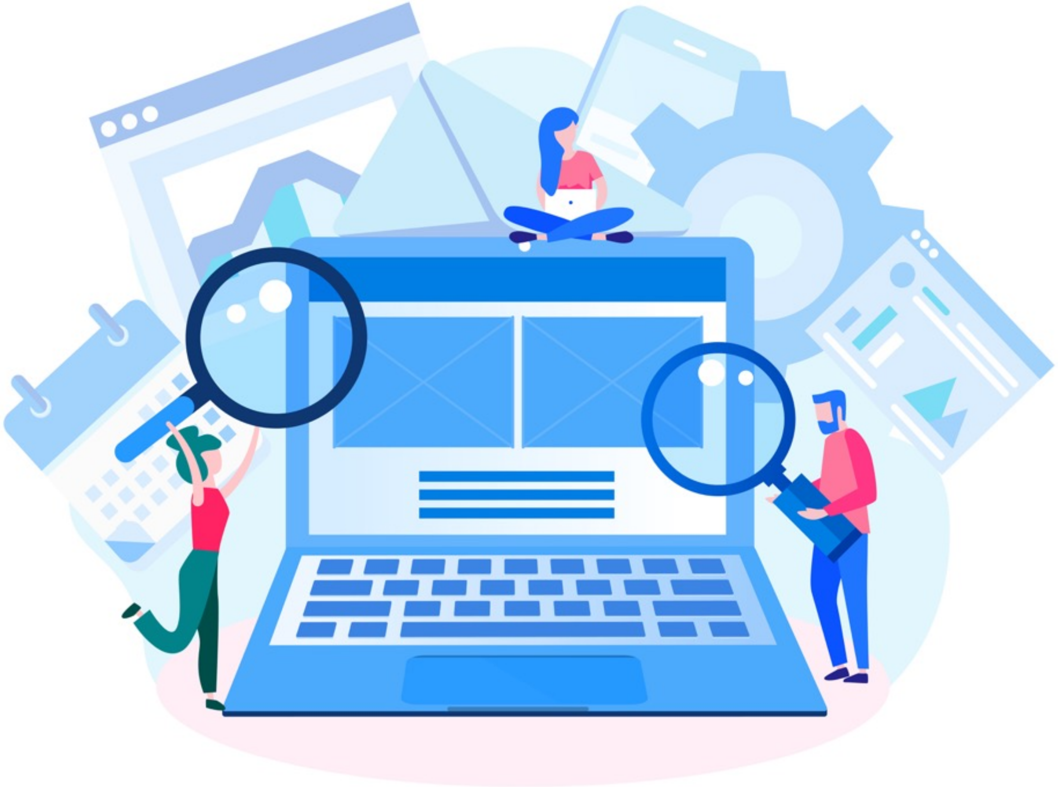
Notes

- Labs 5 and 6 require use of TotalView's Classic UI
- Sample program breakpoint files were created with GNU compilers. If a different compiler is used, they may not load and will need to be recreated.
- Several example programs use OpenMPI so you will need to configure your environment beforehand.
- We do not have a lab specific to Python Debugging yet. There are good examples and instructions in the TotalView *totalview.2020.3.11/<linux-x86-64>/examples/PythonExamples* directory.

TotalView Features

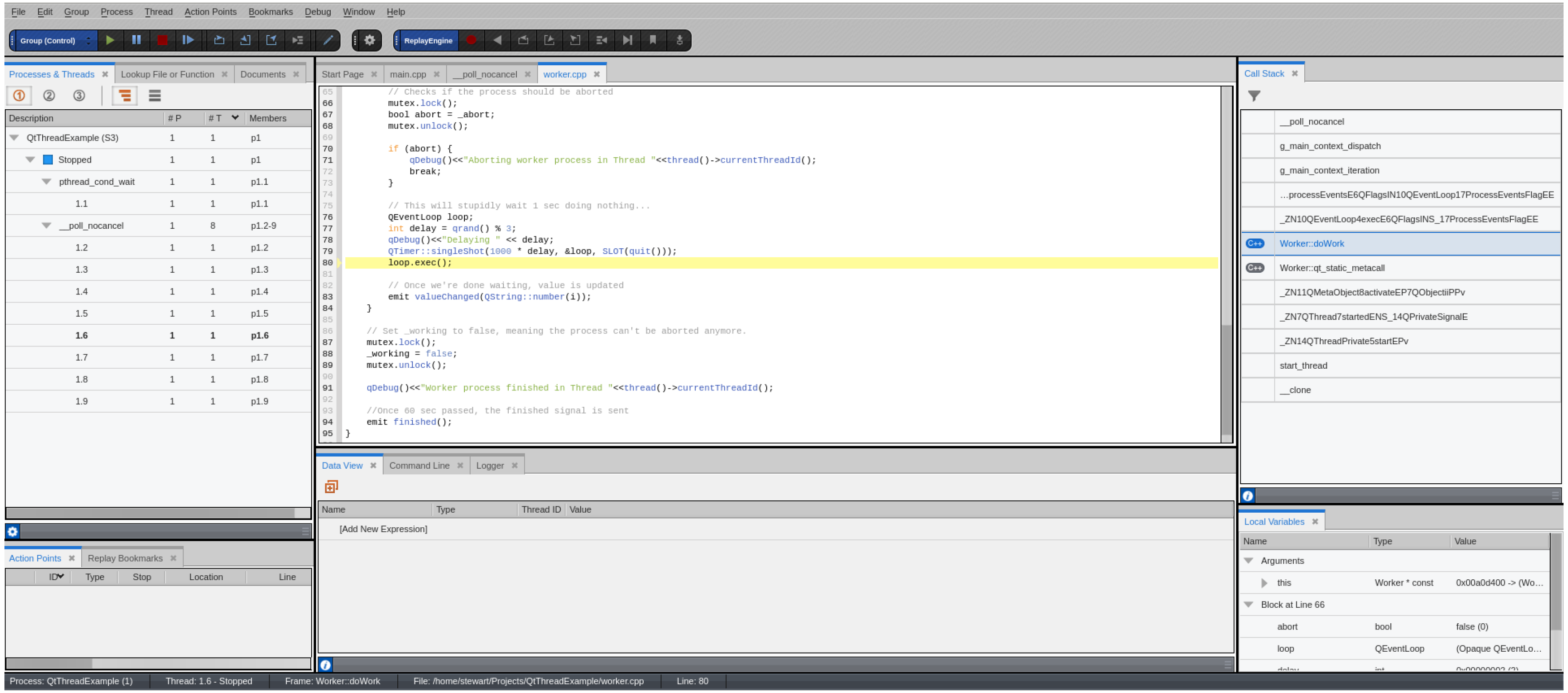
What is TotalView used for?

- Provides interactive Dynamic Analysis capabilities to help:
  - Understand complex code
  - Improve code quality
  - Collaborate with team members to resolve issues faster
  - Shorten development time
- Finds problems and bugs in applications including:
  - Program crash or incorrect behavior
  - Data issues
  - Application memory leaks and errors
  - Communication problems between processes and threads
  - CUDA application analysis and debugging
- Contains batch and Continuous Integration capabilities to:
  - Debug applications in an automated run/test environment



TotalView Features

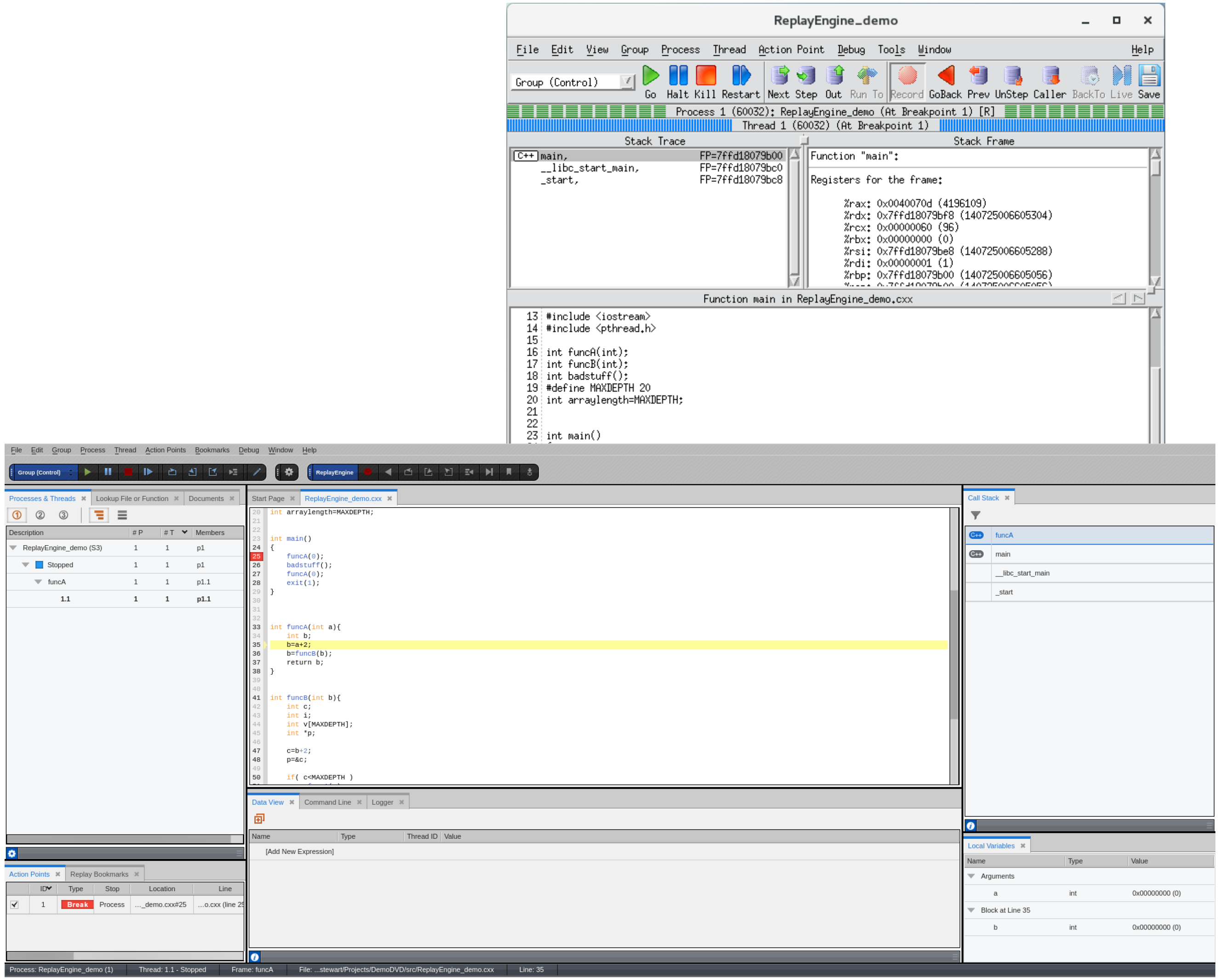
- Comprehensive C, C++ and Fortran multi-process/thread dynamic analysis and debugging
  - Thread specific breakpoints with individual thread control
  - View thread specific stack and data
  - View complex data types easily
- MPI and OpenMP HPC debugging
- CUDA debugging
- Integrated Reverse debugging
- Mixed Language - Python C/C++ debugging
- Memory leak detection
- Batch/unattended debugging
- Linux, macOS and UNIX
- **More than just a tool to find bugs**
  - Understand complex code
  - Improve developer efficiency
  - Collaborate with team members
  - Improve code quality
  - Shorten development time



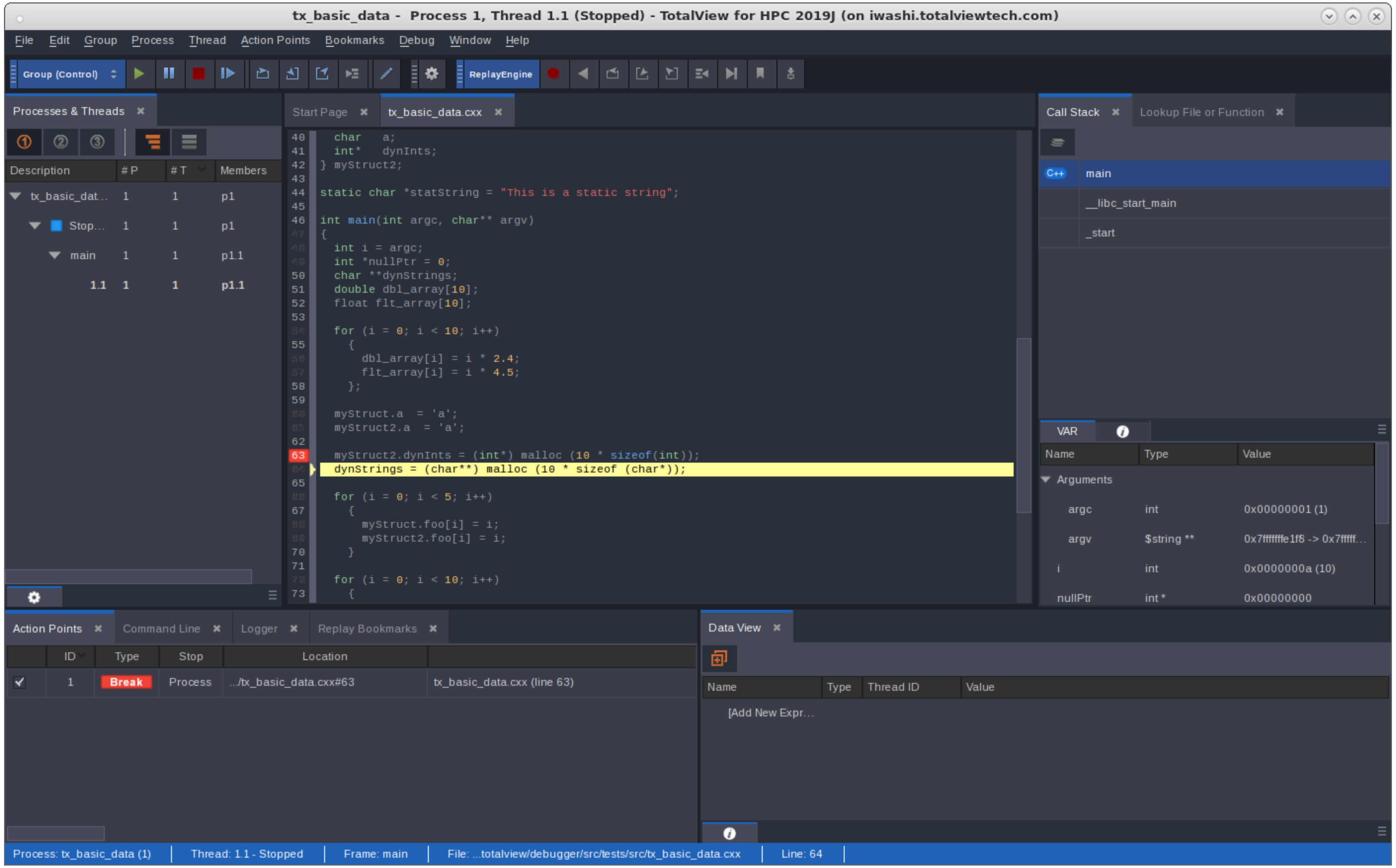
TotalView’s New UI

TotalView's New UI

- Provides a modern, dockable interface
- Easier to use, better workflows
- An architecture to grow
- To use:
  - Set UI preference
  - Or command line argument
    `totalview –newUI or totalview –oldUI`
- New UI gaps:
  - Missing array viewer, data visualization
  - Memory debugging not integrated
  - No high-scale MPI support



TotalView's Dark Theme – 2019.1



Remote Debugging

Remote Debugging Sessions

- Debugging on a remote HPC cluster can be a challenge
  - Setting up the secure remote connection
  - Launching/connecting to the target application
  - Interactive debugging UI
- TotalView Remote Debugging Options
  - **TotalView Remote Display Client**
    - Conveniently setup a remote VNC connection
  - **TotalView Reverse Connect**
    - Disconnect launching the core debugger within the cluster from the UI on a front-end node
  - **TotalView Remote UI**
    - Run the TotalView UI on a remote client and connect to the remote TotalView debugger

TotalView Remote Display Client (RDC)

- Offers users the ability to easily set up and operate a TotalView debug session that is running on another system
- Consists of three components
  - Client – runs on local machine
  - Server – runs on any system supported by TotalView and "invisibly" manages the secure connection between host and client
  - Viewer – window that appears on the client system
- Remote Display Client is available for:
  - Linux x86, x86-64
  - Windows
  - Mac OSX

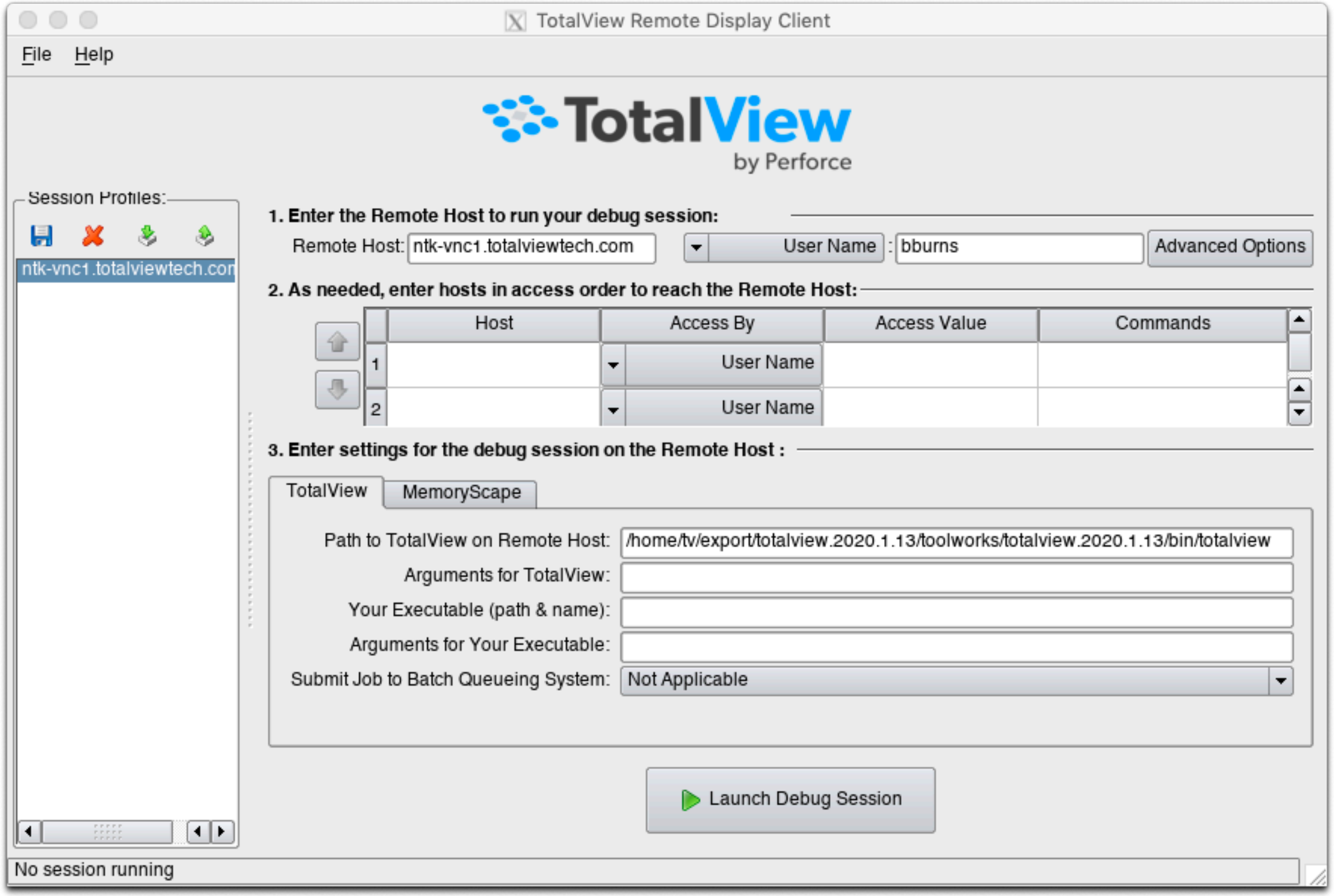
TotalView Remote Display Client

- Free to install on as many clients as needed
- No license required to run the client
- Presents a local window that displays TotalView or MemoryScape running on the remote machine
- Requires SSH and X Windows on Server

TotalView Remote Display Client

- User must provide information necessary to connect to remote host
- Passwords are NOT stored
- Information required includes:
    - User name, public key file, other ssh information
    - Directory where TotalView/MemoryScape is located
    - Path and name of executable to be debugged
    - If using indirect connection with host jump, each host
        - Host name
        - Access type (User name, public key, other ssh information)
        - Access value
- Client also allows for batch submission via PBS Pro or LoadLeveler

TotalView Remote Display Client



Session Profile Management

- Connection information can be saved as a profile, including all host jumping information
- Multiple profiles can be generated
- Profiles can be exported and shared
- Generated profiles can be imported for use by other users

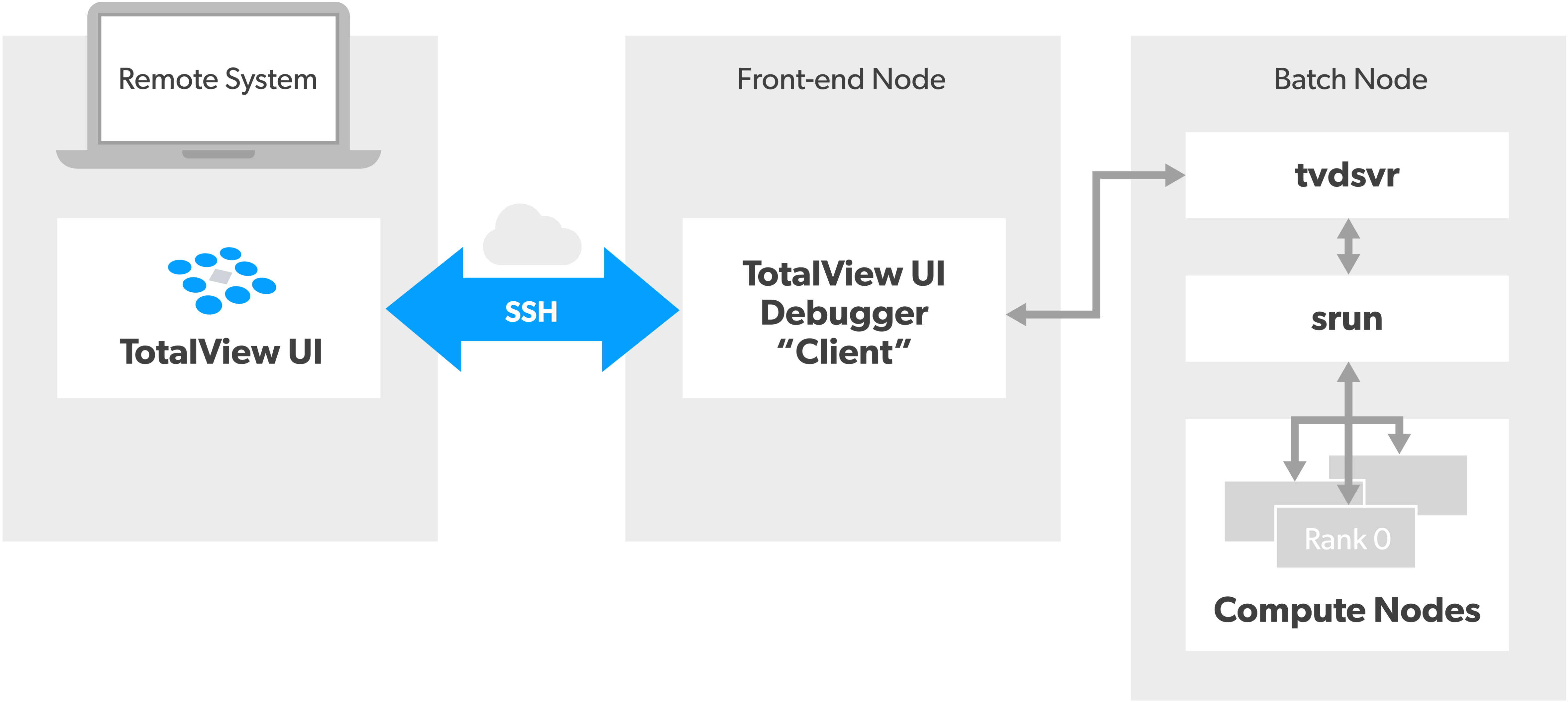
RDC Demo

- Remote Display Client demo (Linux)

TotalView Remote UI (TotalView 2020.3)

- Combine the convenience of establishing a remote connection to a cluster and the ability to run the TotalView GUI locally.
- Front-end GUI architecture does not need to match back-end target architecture (macOS front-end -> Linux back-end)
- Secure communications
- Convenient saved sessions
- Supports reverse connections

Remote UI Architecture



TotalView Reverse Connections

- The organization of modern HPC systems often makes it difficult to deploy tools such as TotalView
- The compute nodes in a cluster may not have access to any X libraries or X forwarding
- Launching a GUI on a compute node may not be possible
- Using the Reverse Connect feature you can start the TotalView UI on a front end node and when a job is run in the cluster it connects back to the waiting UI

Reverse Connect

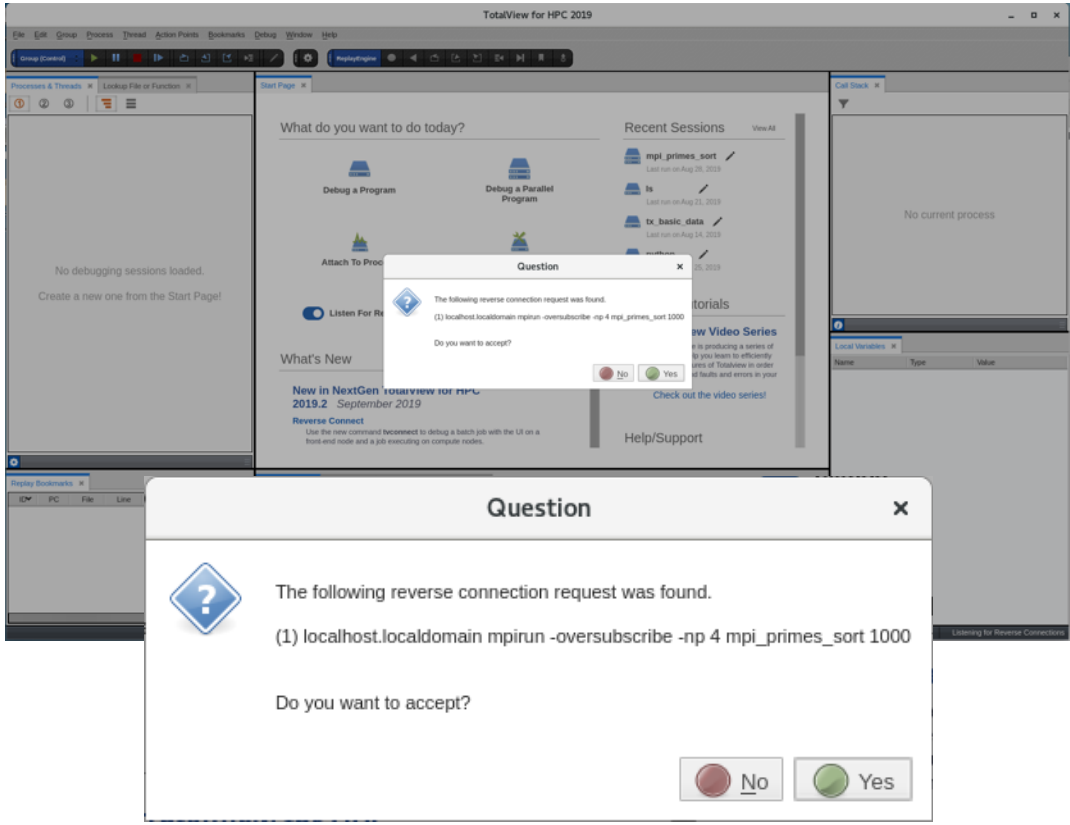
- Useful in batch environments, where
  - X11 libraries or X forwarding are not available
  - You typically use batch scripts

- TotalView's reverse connect feature
  - Disconnects starting debugger UI from backend job launch
  - Starts a TotalView server on the batch node

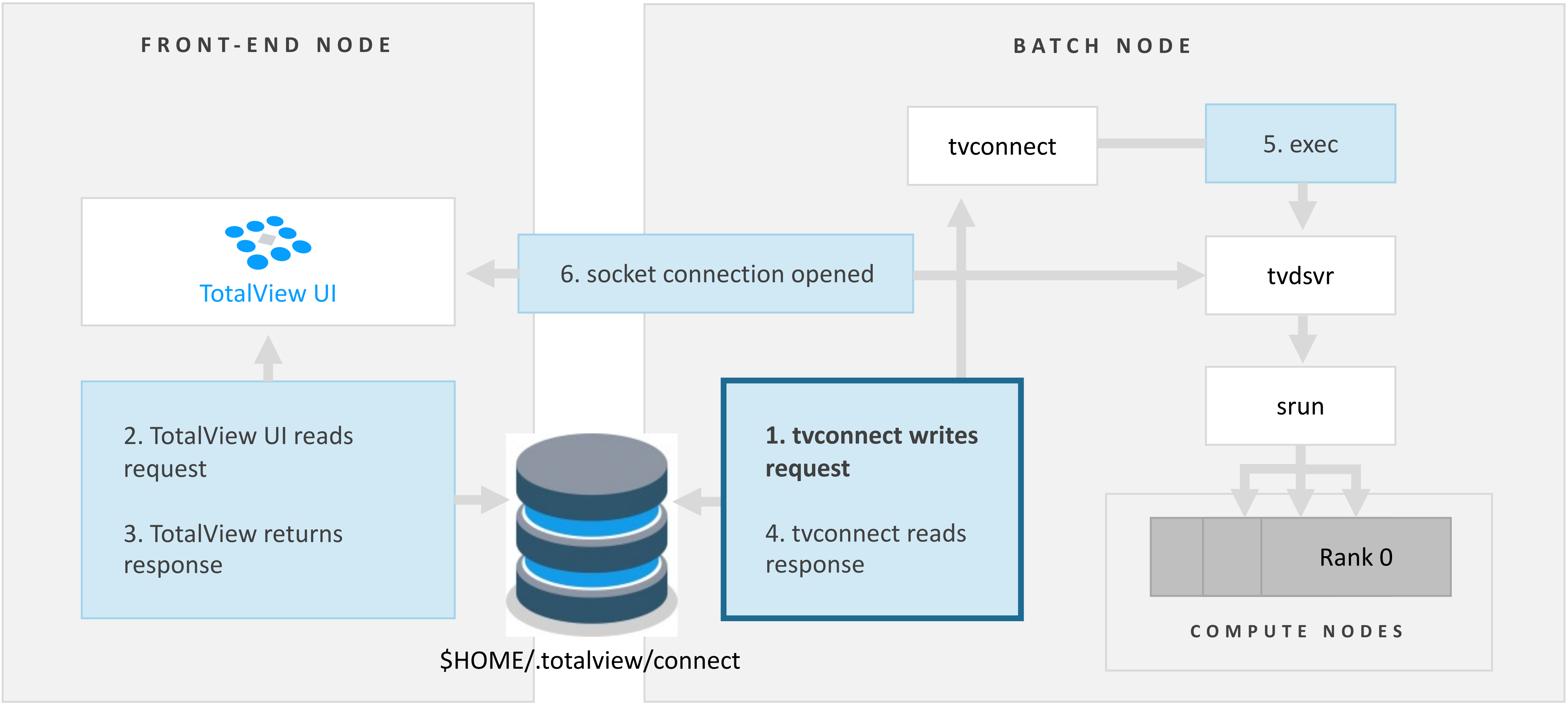
Batch Script Submission with Reverse Connect

- Start a debugging session using TotalView Reverse Connect.
- Reverse Connect enables the debugger to be submitted to a cluster and connected to the GUI once run.
- Enables running TotalView UI on the front-end node and remotely debug jobs executing on the compute nodes.
- Very easy to utilize, simply prefix job launch or application start with “tvconnect” command.

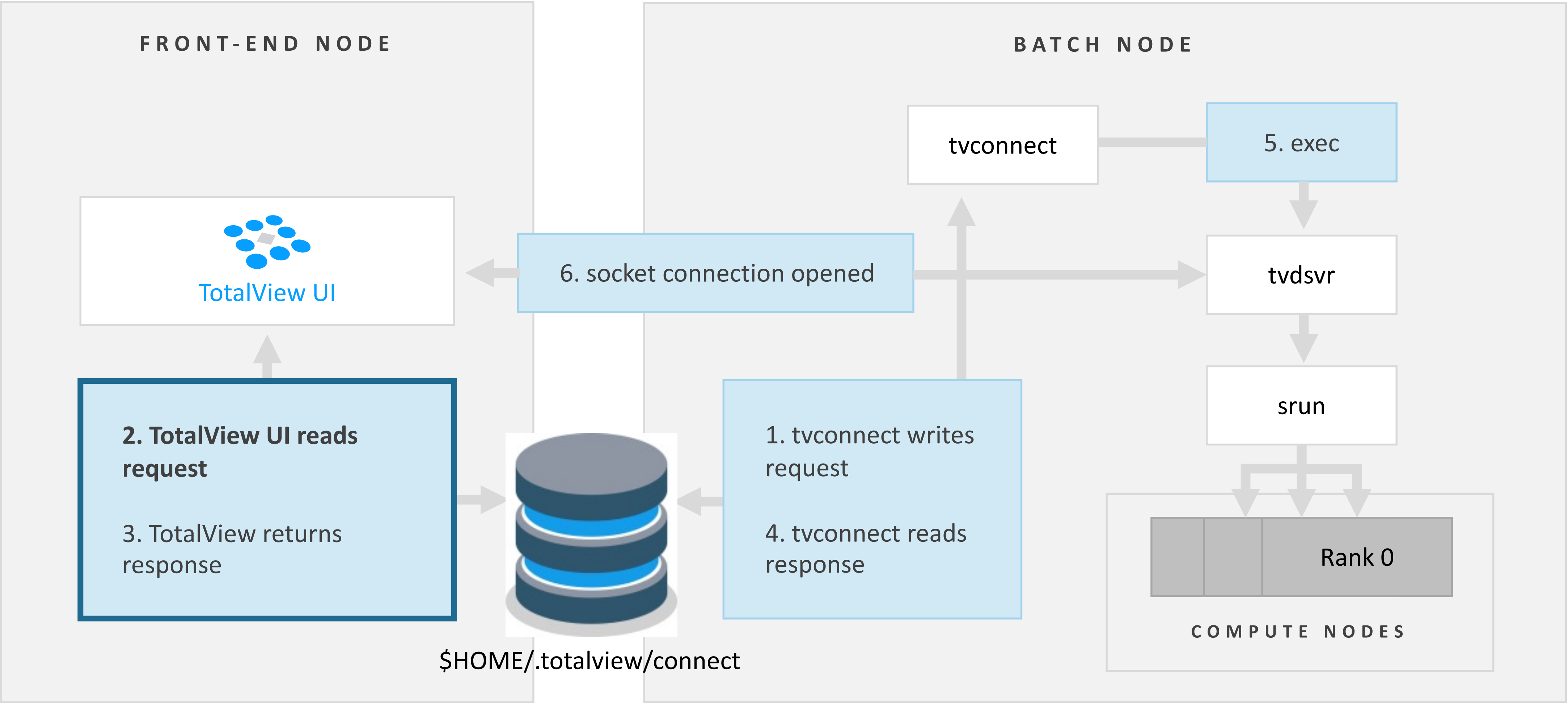
```
#!/bin/bash
#SBATCH -J hybrid_fib
…
#SBATCH -n 2
#SBATCH -c 4
#SBATCH --mem-per-cpu=4000
export OMP_NUM_THREADS=4
tvconnect srun -n 2 --cpus-per-task=4 --mpi=pmix ./hybrid_fib
```



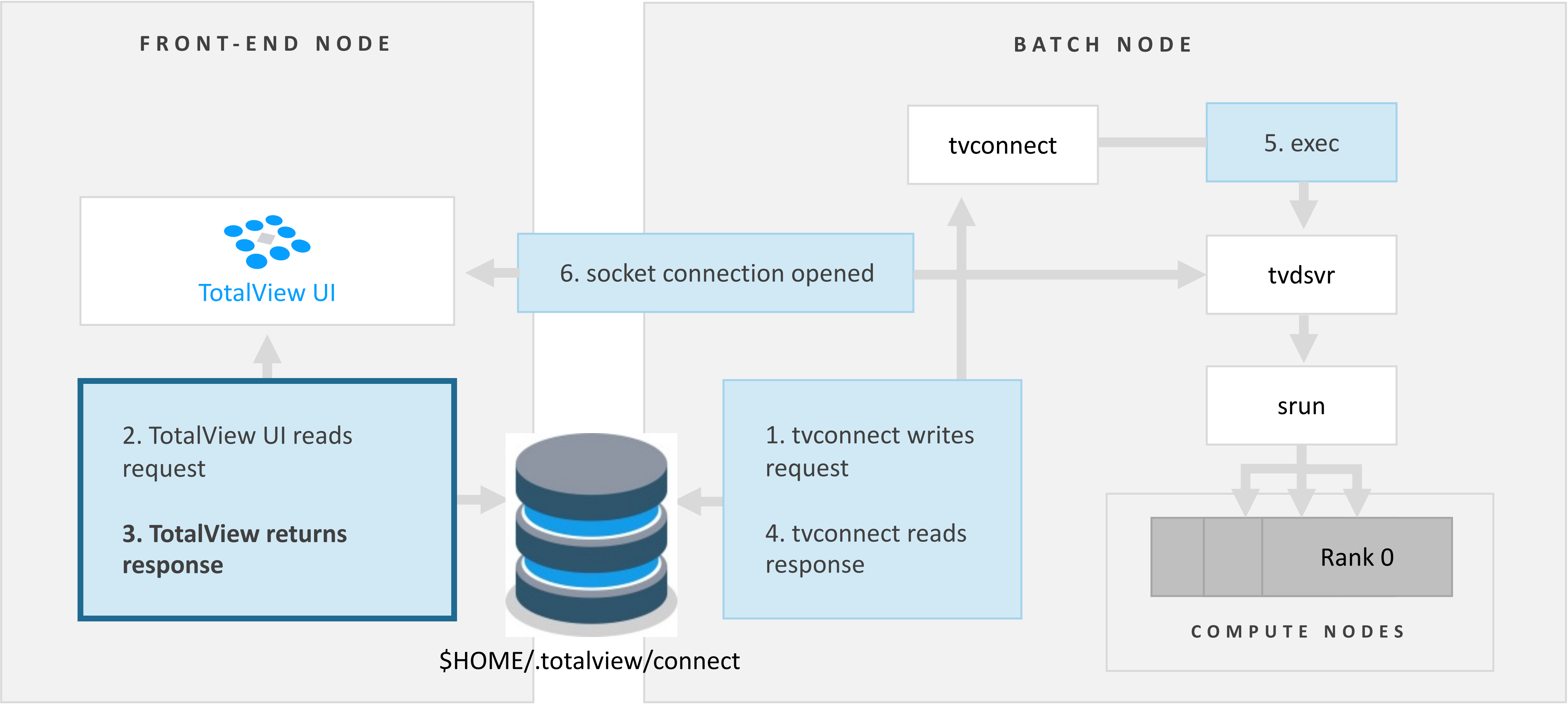
Reverse Connection Flow



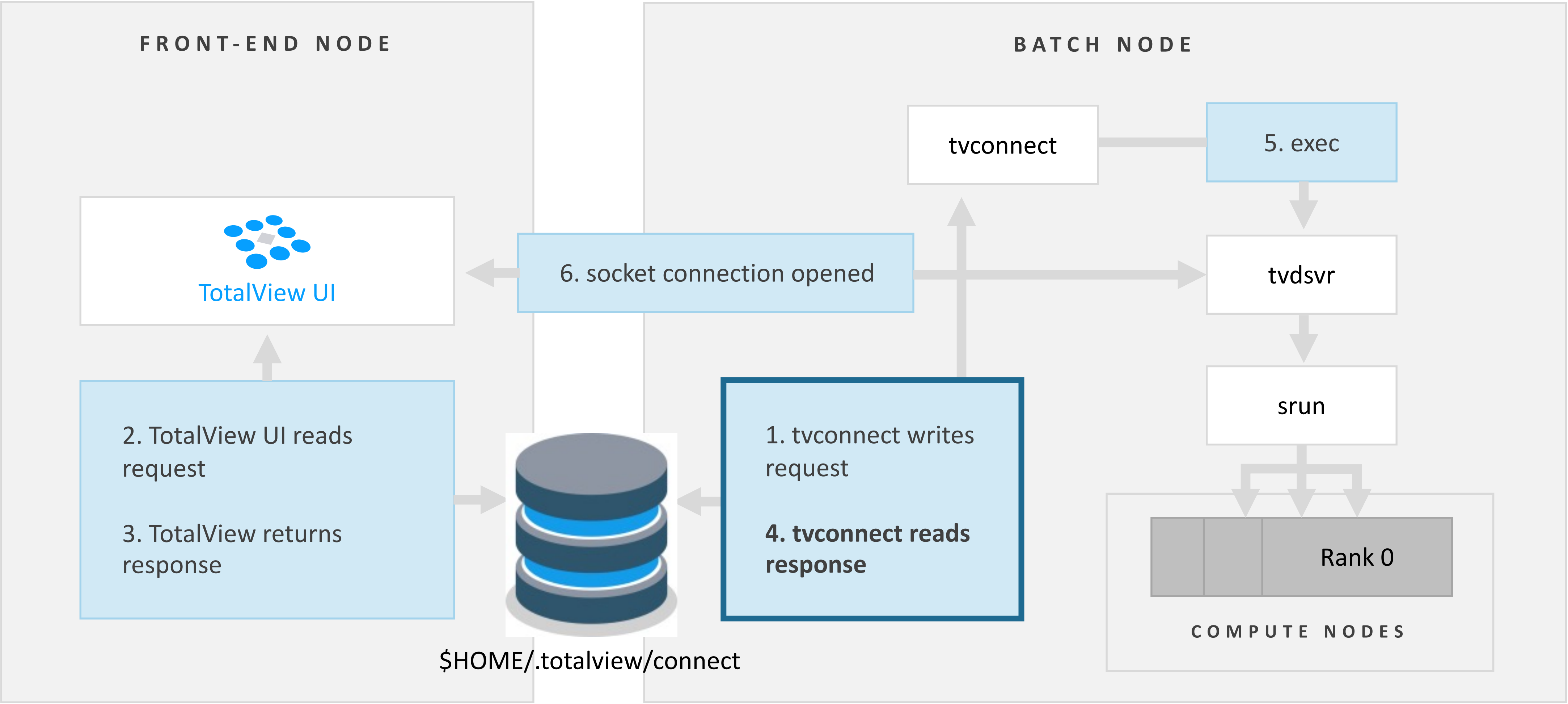
Reverse Connection Flow



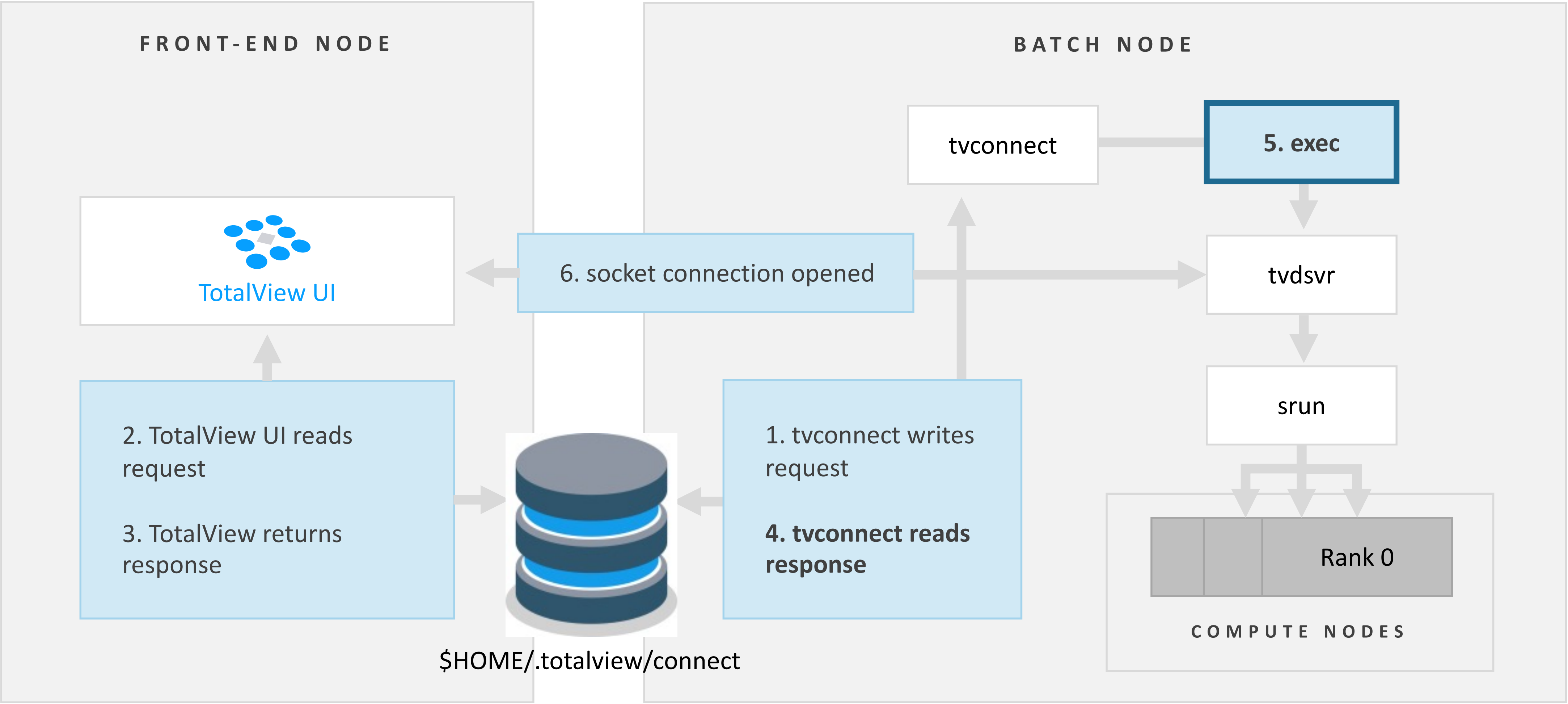
Reverse Connection Flow



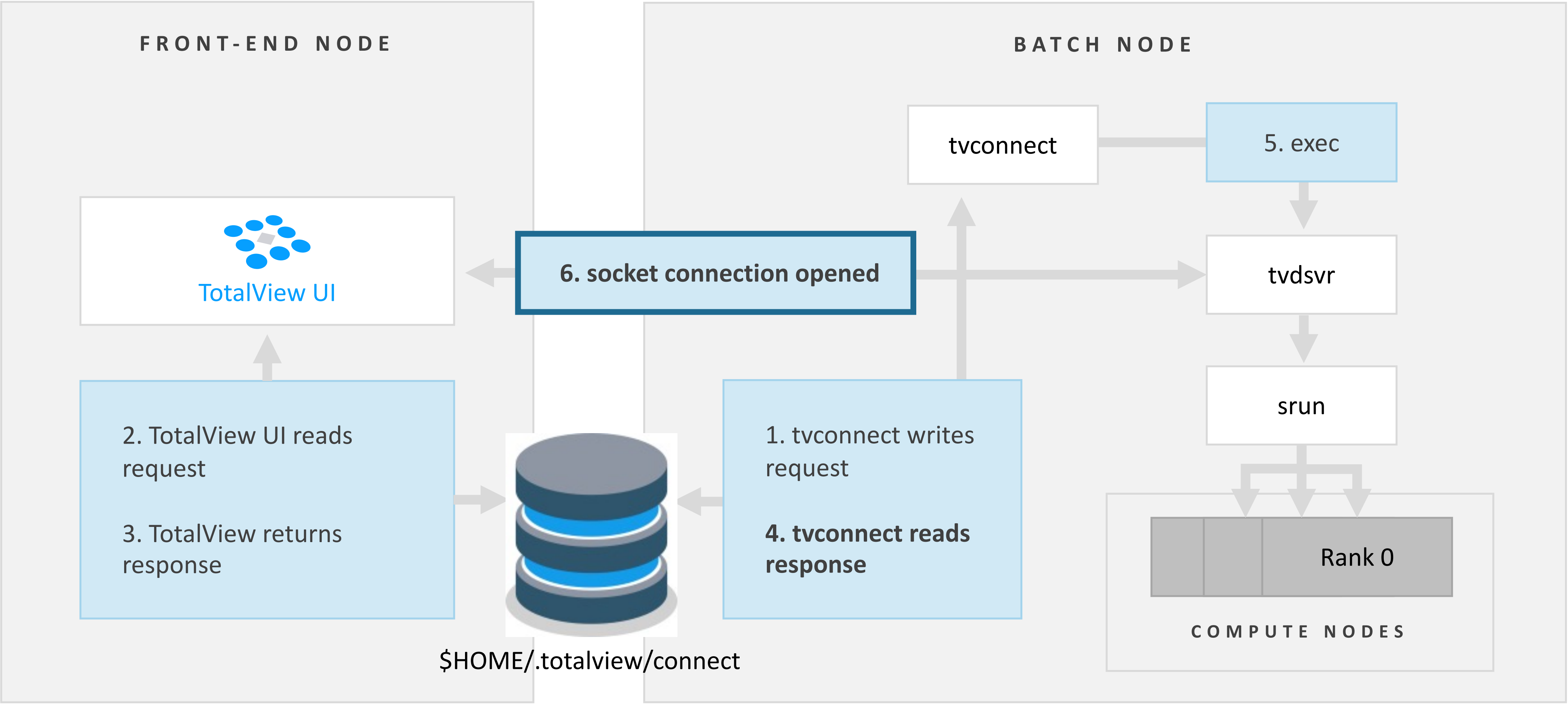
Reverse Connection Flow



Reverse Connection Flow



Reverse Connection Flow

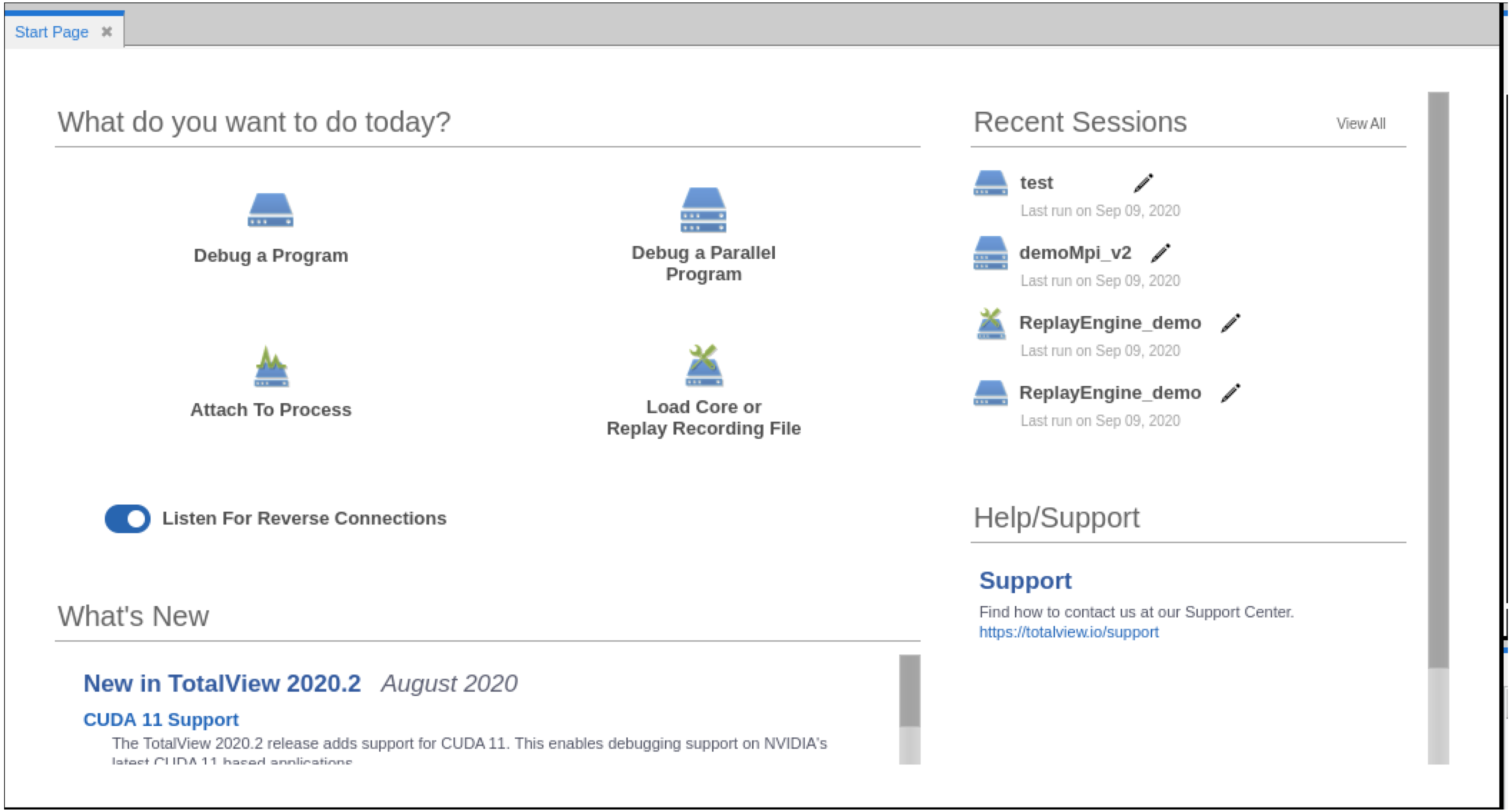


Remote UI with Reverse Connect Demo

- TotalView Remote UI and Reverse Connect

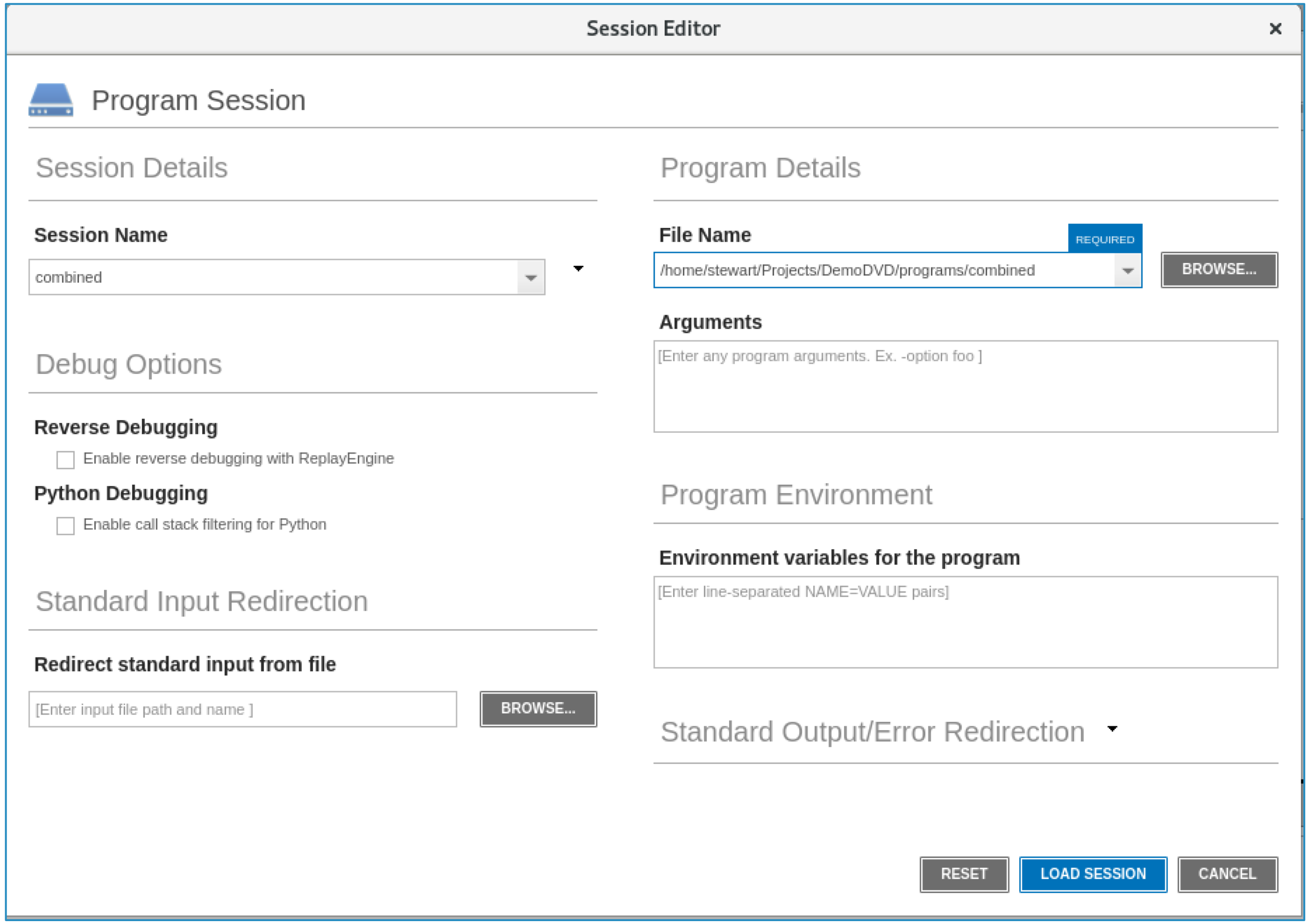
Startup

Start Page

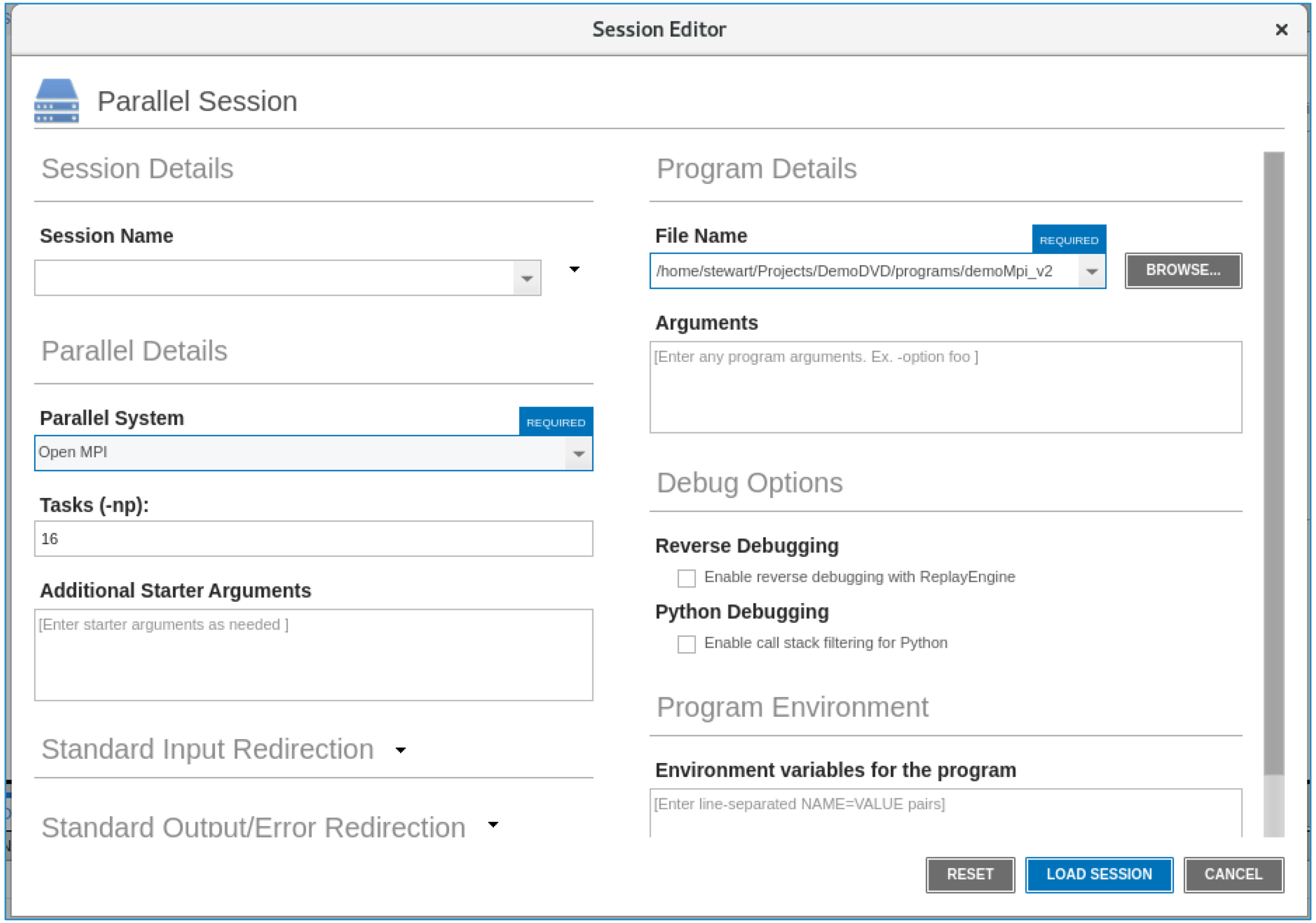


Start Page
What do you want to do today?
Debug a Program
Debug a Parallel Program
Attach To Process
Load Core or Replay Recording File
Listen For Reverse Connections
What's New
New in TotalView 2020.2 August 2020
CUDA 11 Support
The TotalView 2020.2 release adds support for CUDA 11. This enables debugging support on NVIDIA's
Recent Sessions
View All
test
Last run on Sep 09, 2020
demoMpi_v2
Last run on Sep 09, 2020
ReplayEngine_demo
Last run on Sep 09, 2020
ReplayEngine_demo
Last run on Sep 09, 2020
Help/Support
Support
Find how to contact us at our Support Center.
https://totalview.io/support

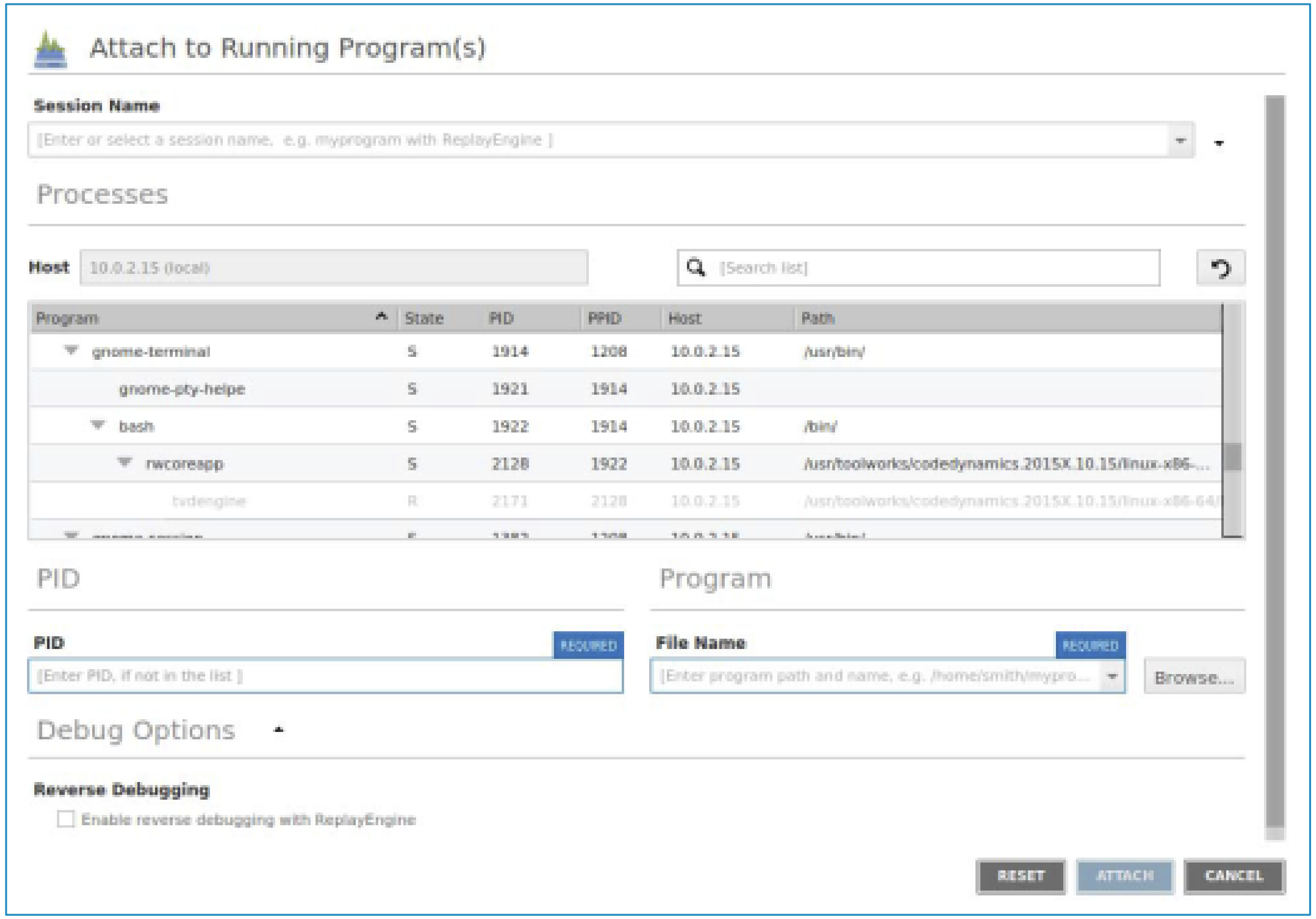
Debugging a New Program



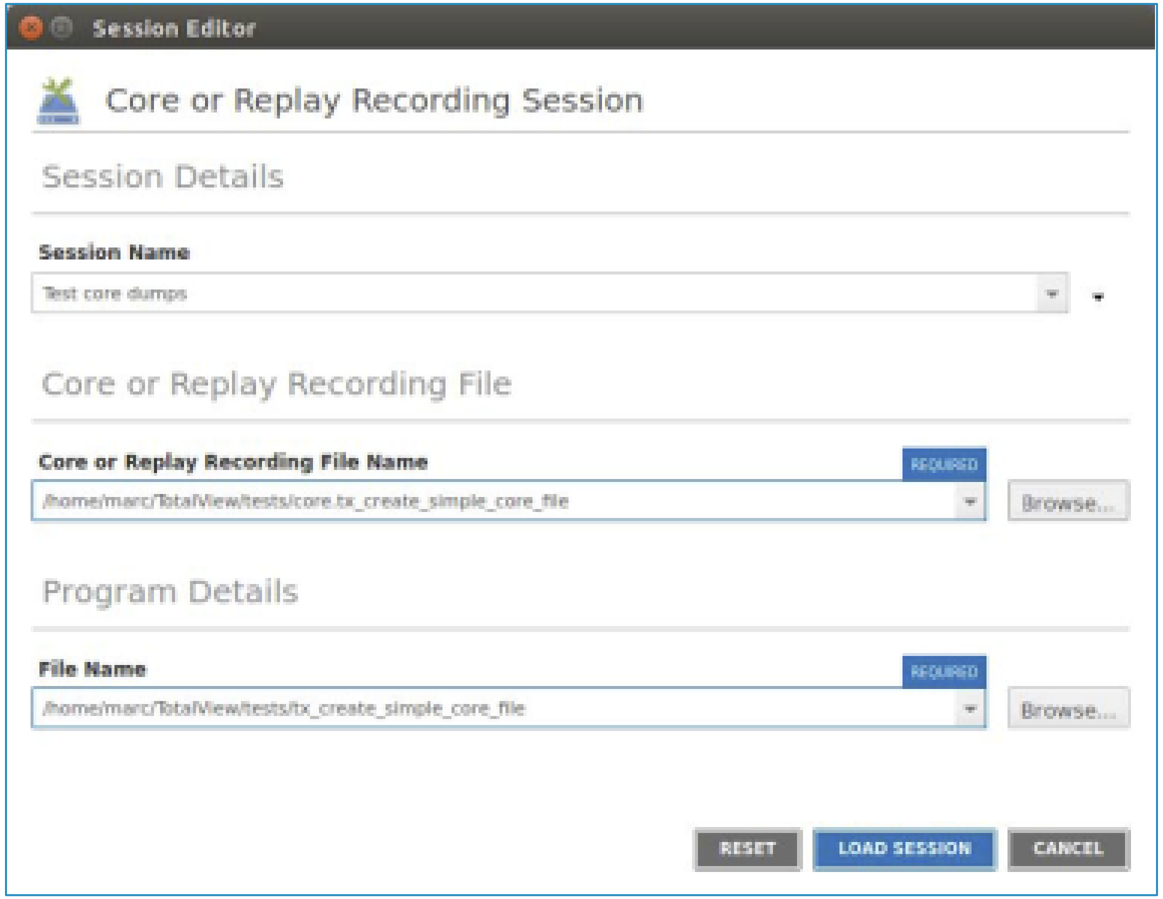
Debugging a Parallel Program



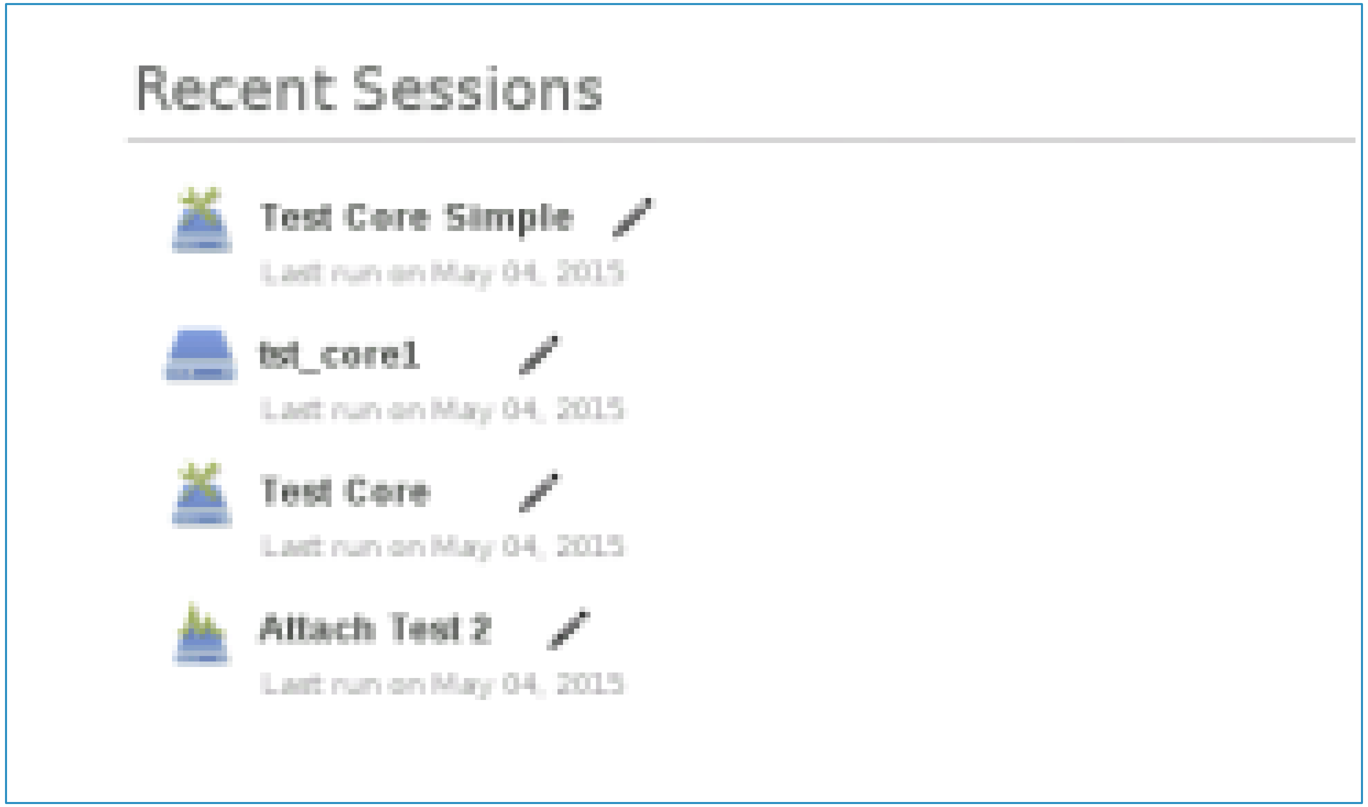
Attach to a Running Program



Open a Core File or Replay Recording Session



Starting a Previous Debugging Session



UI Navigation and Process Control

TotalView's Default Views

Processes & Threads View

Lookup File or Function

Documents

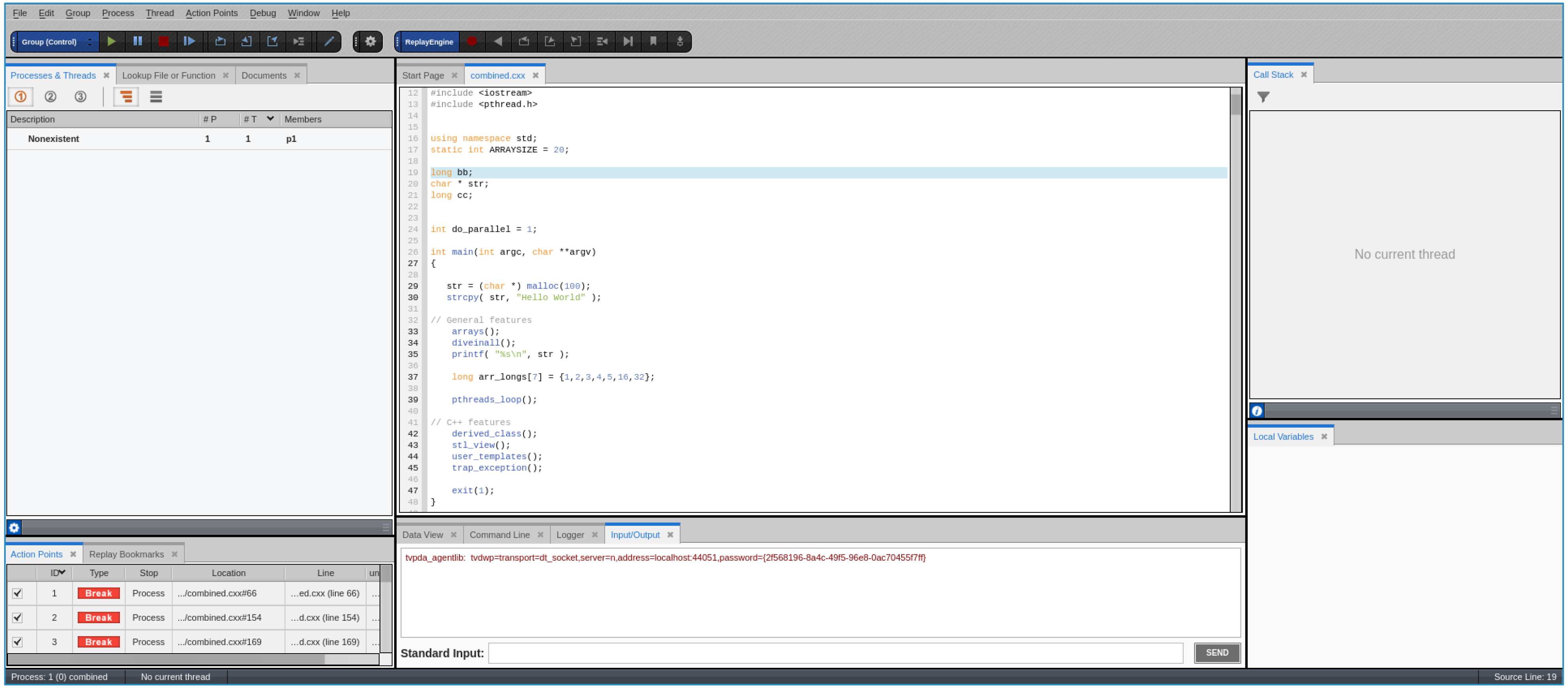
Source View

Call Stack View

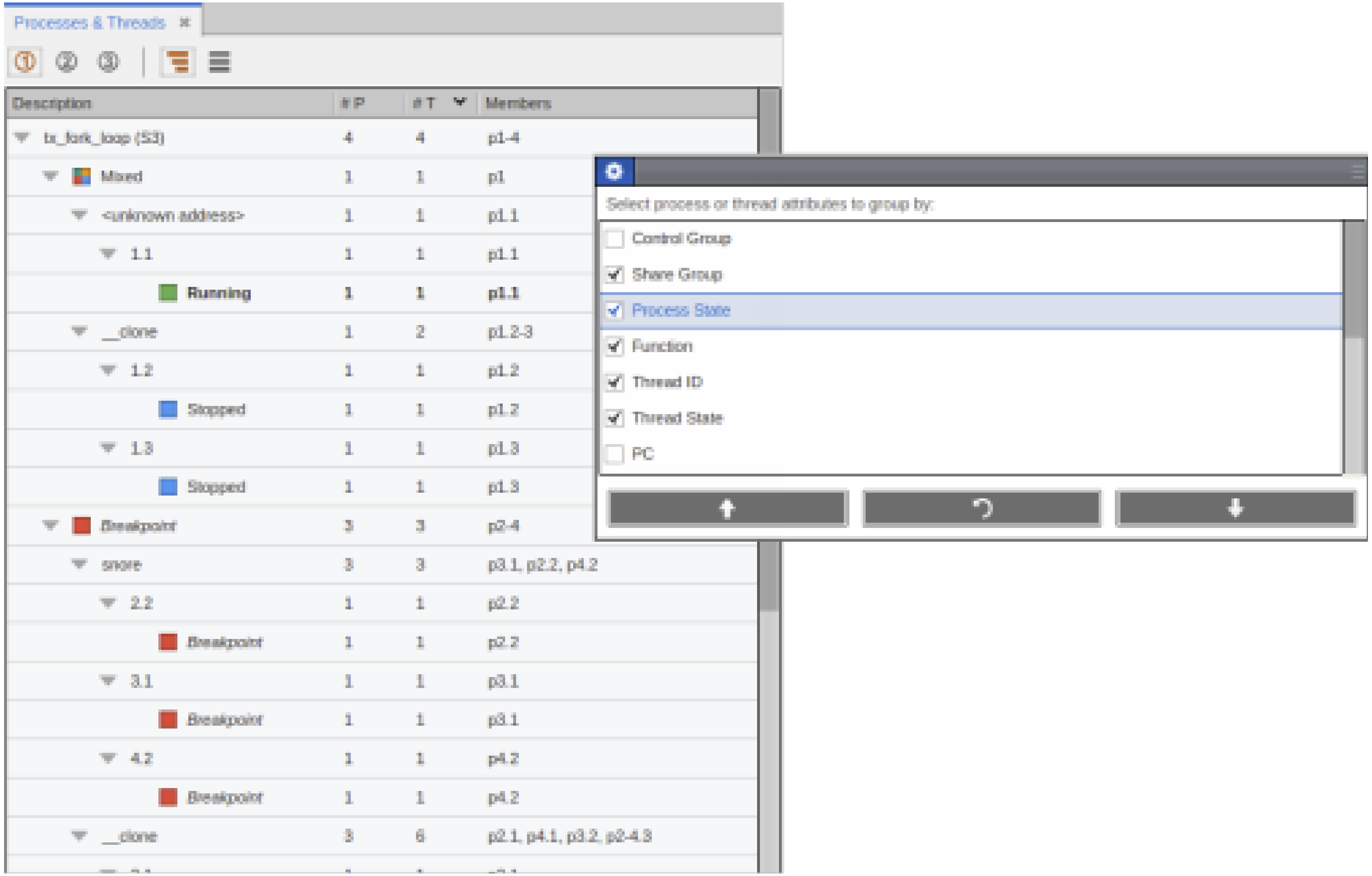
Local Variables View

Data View, Command Line, Logger, Input/Output

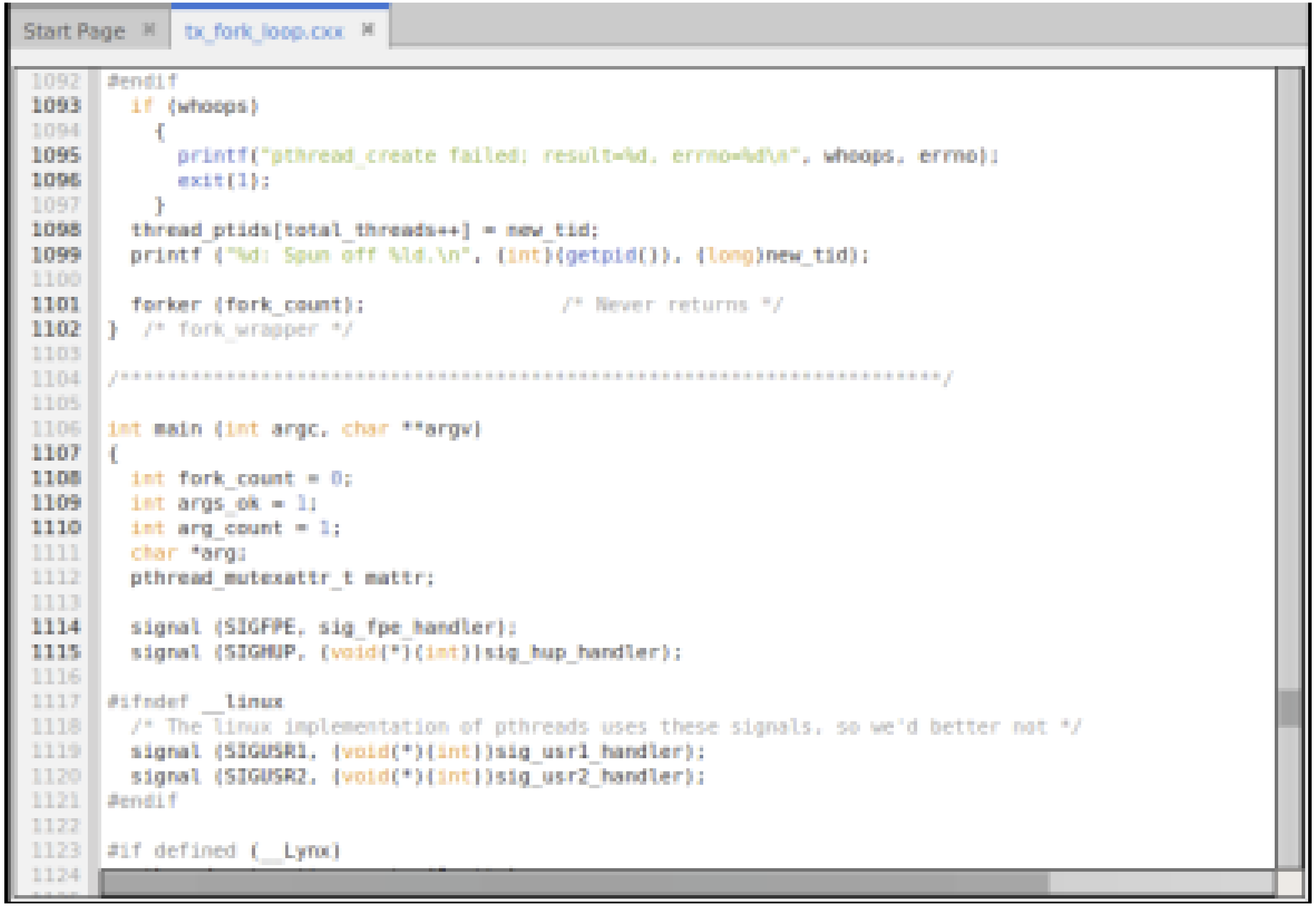
Action Points, Replay Bookmarks



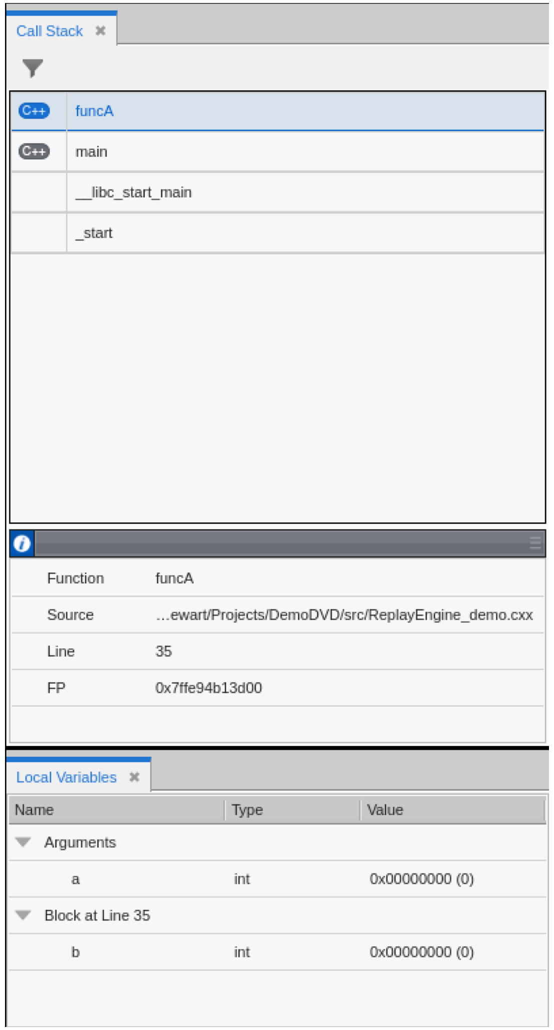
Process and Threads View



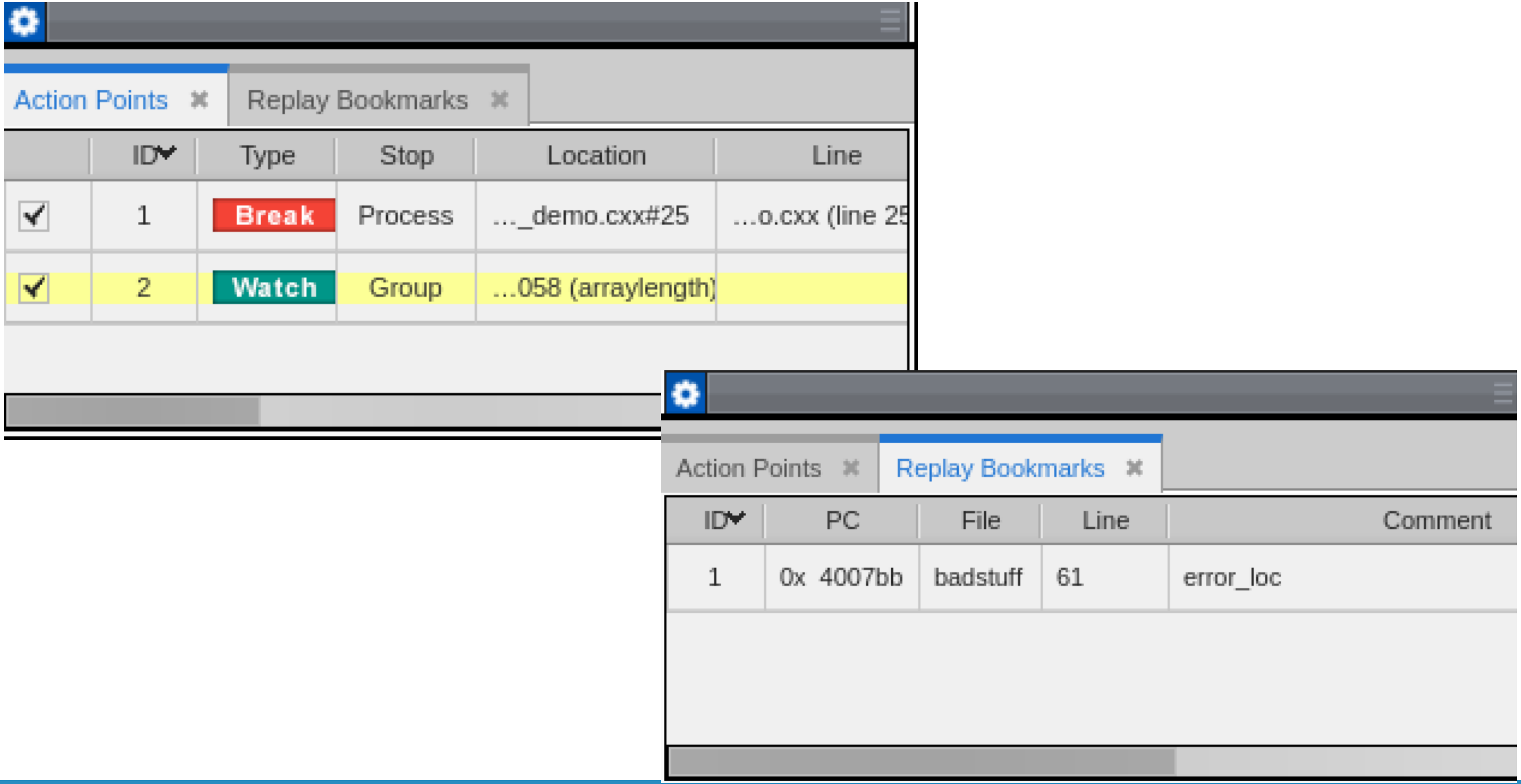
Source View


Start Page
tx_fork_loop.cxx
#endif
if (whoops)
{
printf("pthread_create failed: result=%d, errno=%d\n", whoops, errno);
exit(1);
}
thread_ptids[total_threads++] = new_tid;
printf ("%d: Spun off %ld.\n", (int)(getpid()), (long)new_tid);
forker (fork_count); /* Never returns */
} /* fork_wrapper */
/**/
int main (int argc, char **argv)
{
int fork_count = 0;
int args_ok = 1;
int arg_count = 1;
char *arg;
pthread_mutexattr_t mattr;
signal (SIGFPE, sig_fpe_handler);
signal (SIGHUP, (void(*)(int))sig_hup_handler);
#ifndef __linux
/* The linux implementation of pthreads uses these signals, so we'd better not */
signal (SIGUSR1, (void(*)(int))sig_usr1_handler);
signal (SIGUSR2, (void(*)(int))sig_usr2_handler);
#endif
#if defined (__Lynx)

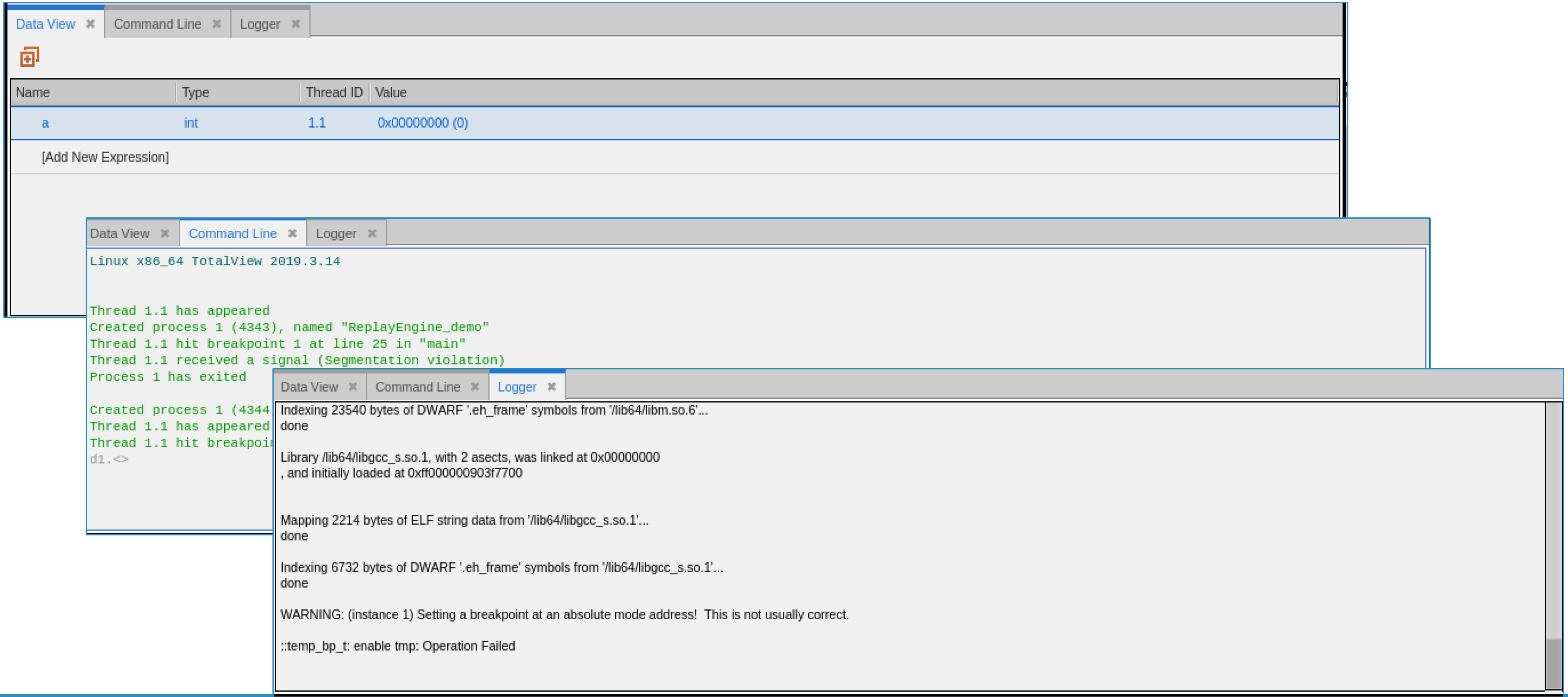
Call Stack View and Local Variables Panel



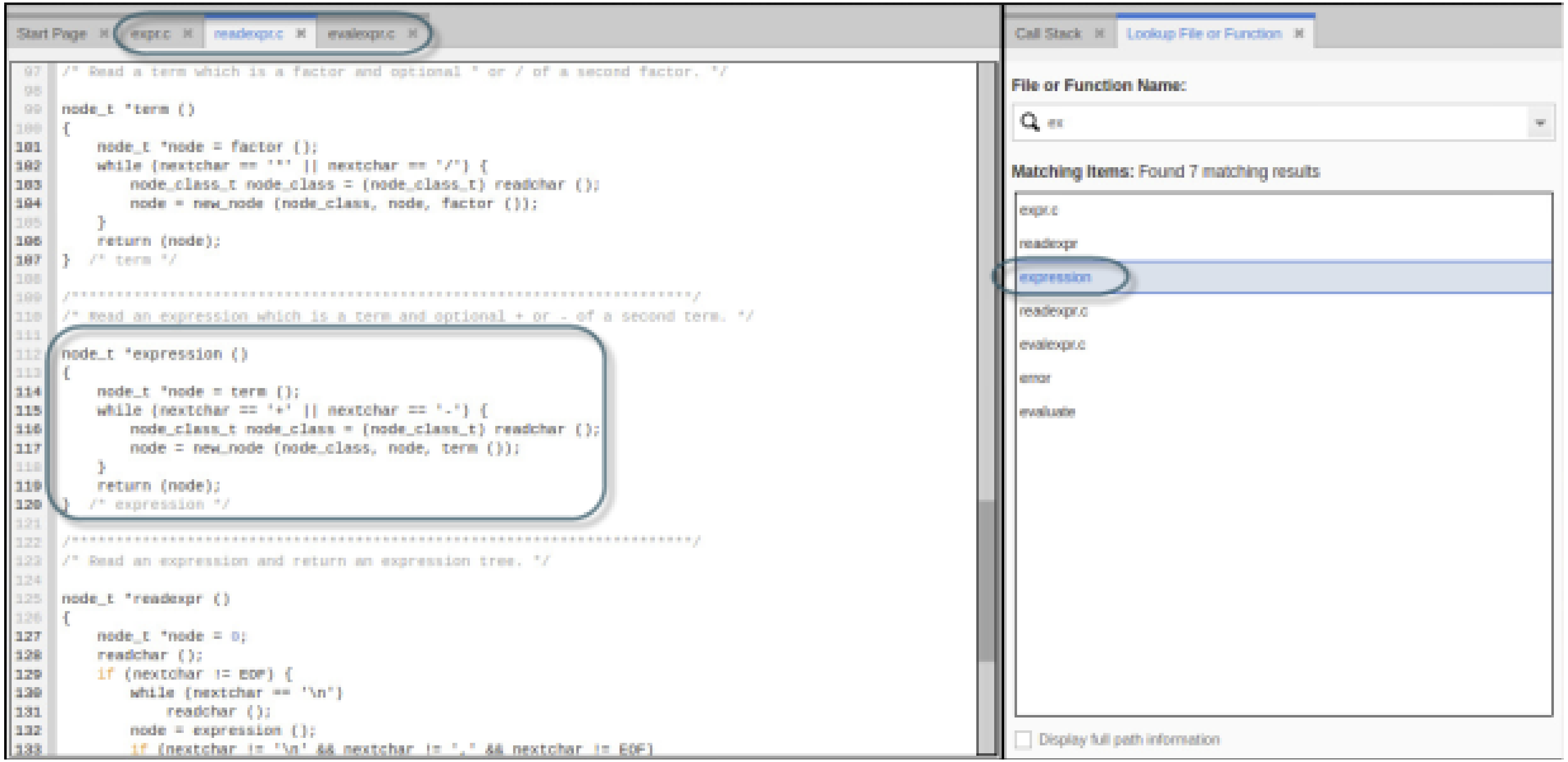
Action Points and Replay Engine Bookmarks



Data View, Command Line and Logger

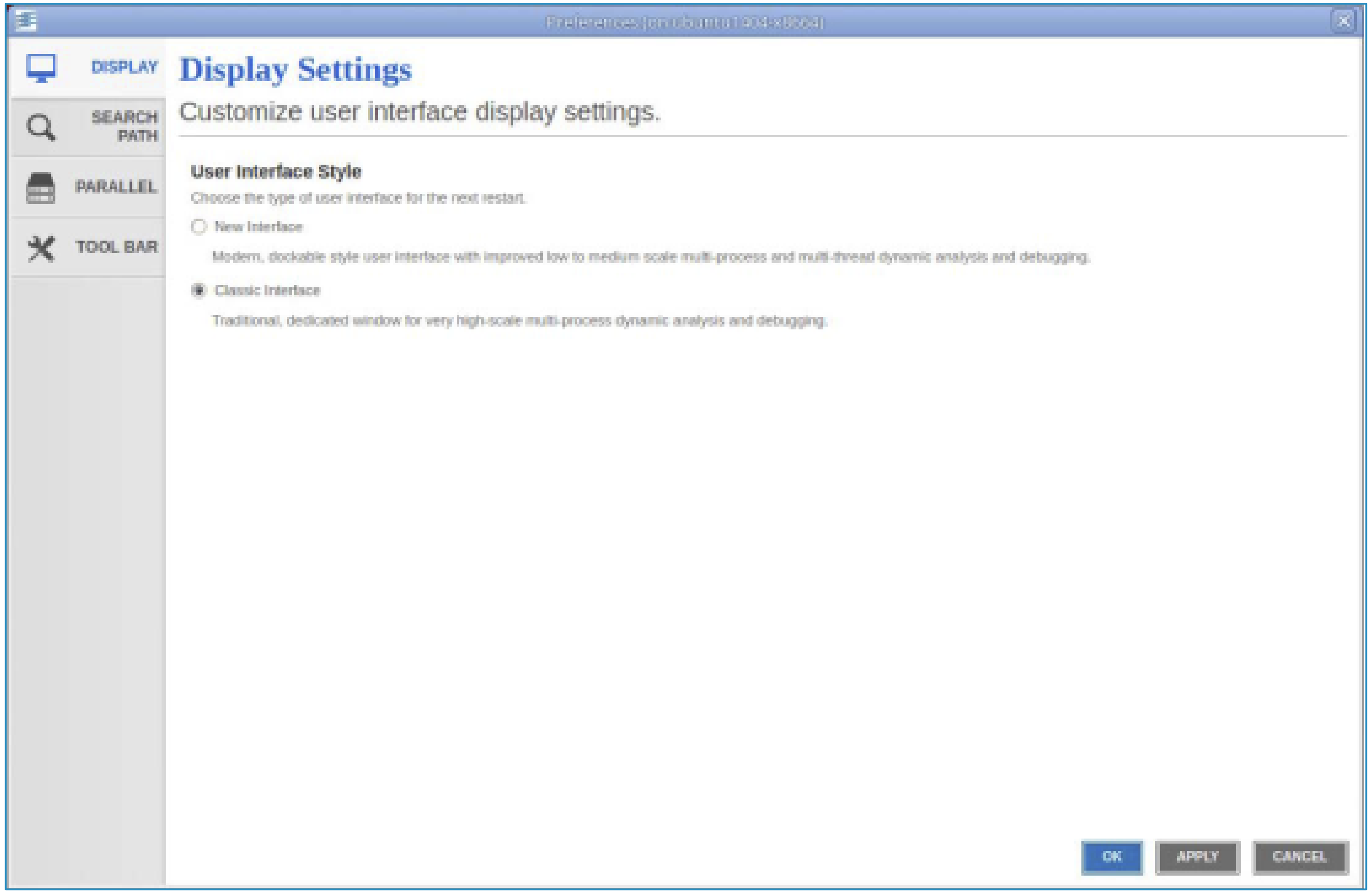


Lookup File or Function

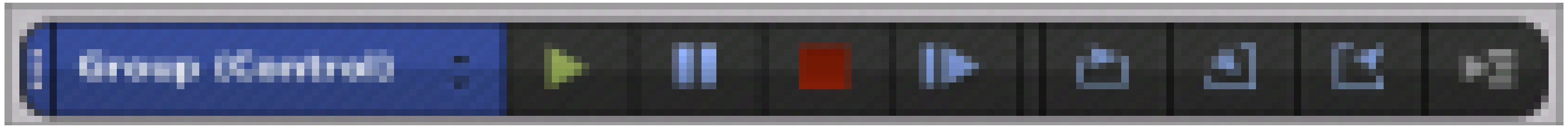


Preferences

Display Settings

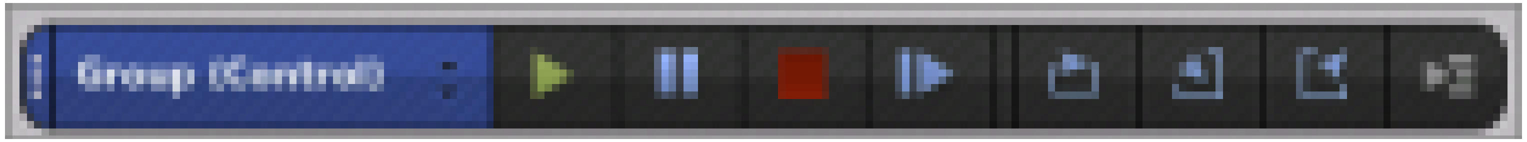


TotalView Toolbar

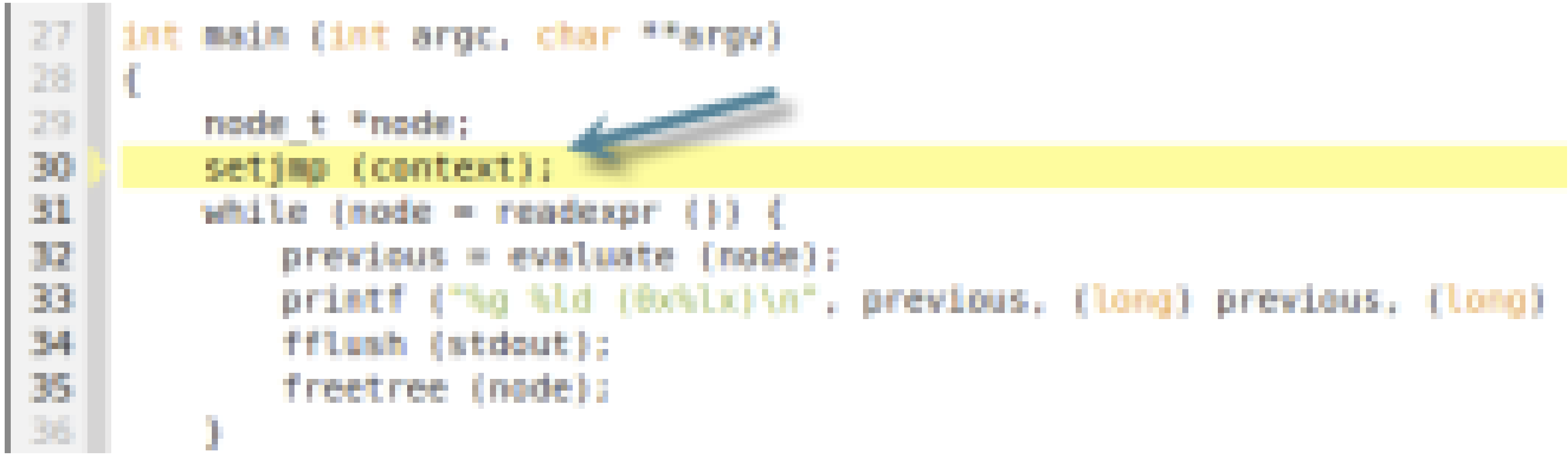


Command	Description
Go	Sets the thread to running until it reaches a stopping point. Often this will be a breakpoint that you have set, but the thread could stop for other reasons.
Halt	Stops the thread at its current execution point.
Kill	Stops program execution. Existing breakpoints and other settings remain in effect.
Restart	Stops program execution and restarts the program from the beginning. Existing breakpoints and other settings remain in effect. This is the same as clicking Kill followed by Go.
Next	Moves the thread to the next line of execution. If the line the thread was on includes one or more function calls, TotalView does not step into these functions but just executes them and returns.
Step	Like Next, except that TotalView does step into any function calls, so the thread stops at the first line of execution of the first function call.
Out	If the thread is in a block of execution, runs the thread to the first line of execution beyond that block.
Run To	If there is a code line selected in one of the Source views, the thread will stop at this line, assuming of course that it ever makes it there. This operates like a one-time, temporary breakpoint.

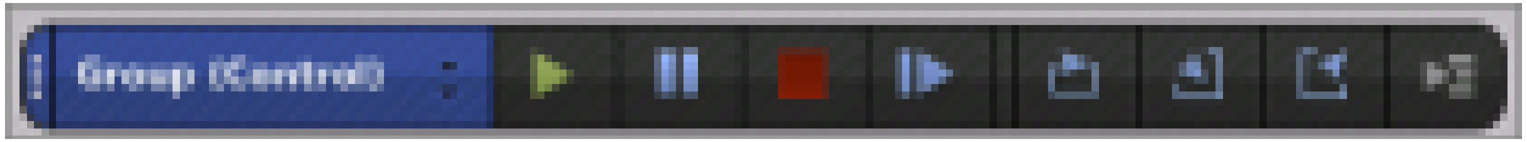
Stepping Commands



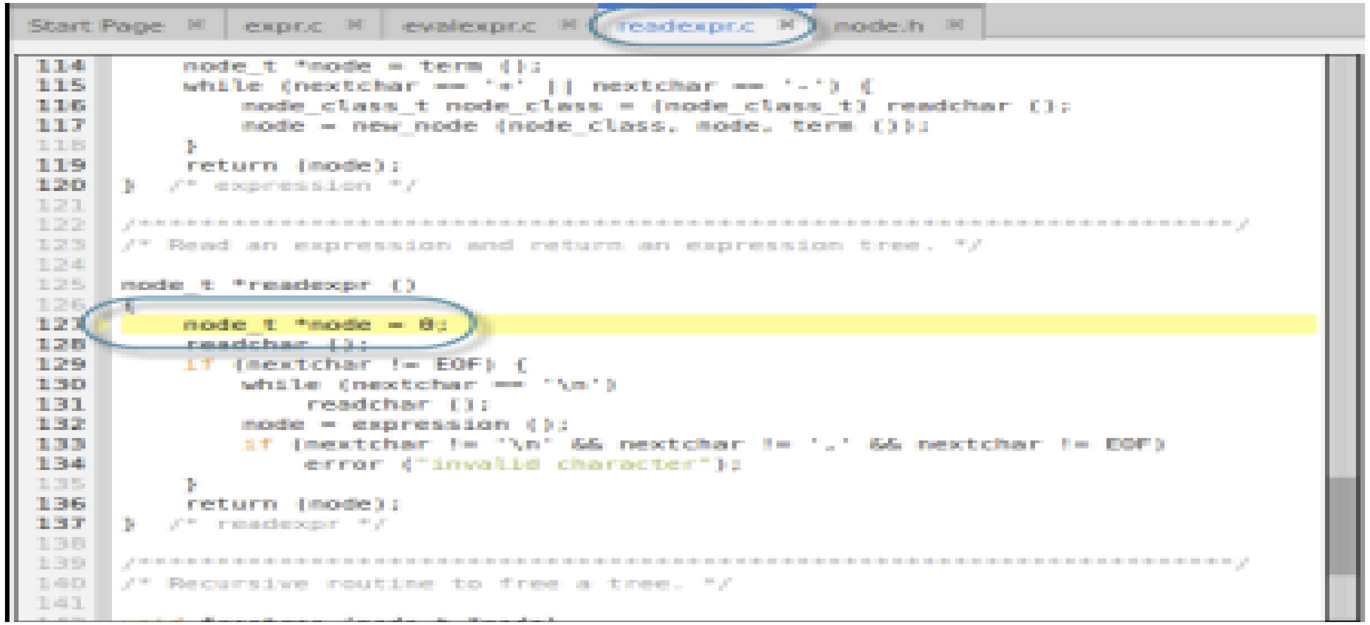
Select Step in the toolbar. TotalView stops the program just before the first executable statement, the call to setjmp (context);



Stepping Commands

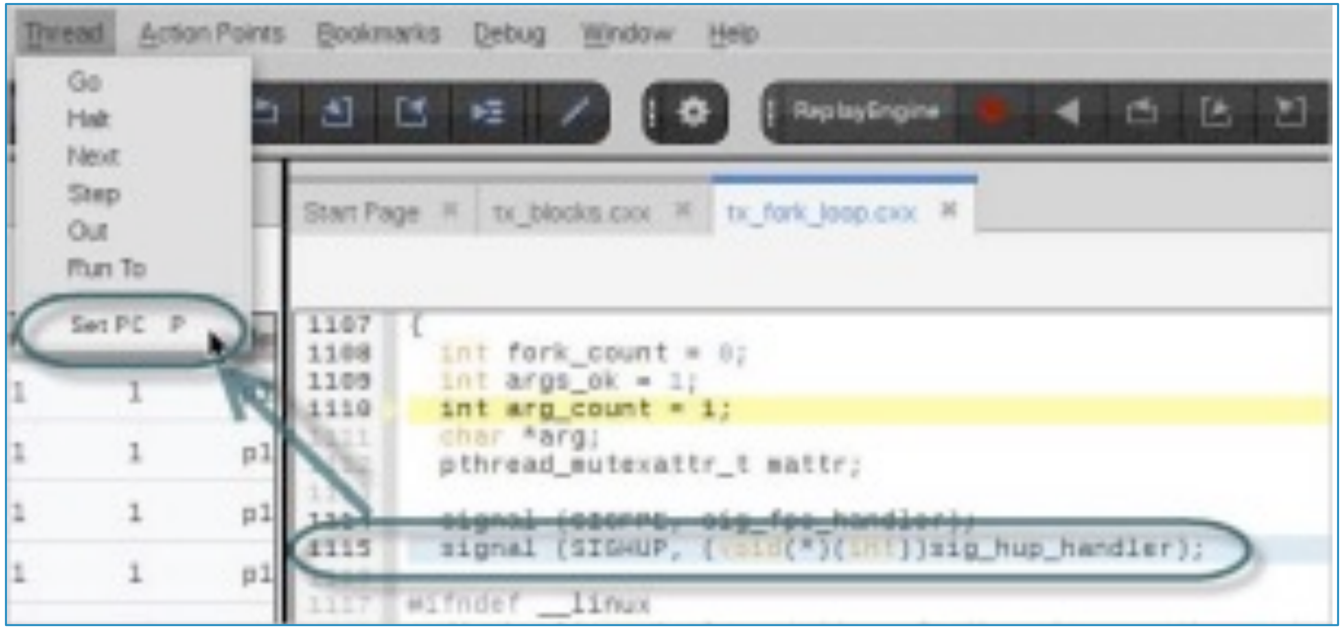


Select Step again to advance to the while loop on line 31, and then select Step again to *step into* the readexpr() function. (Next would *step over,* or execute it).



Using Set PC

- Resumes execution from an arbitrary point
- Select the line
- Thread->Set PC

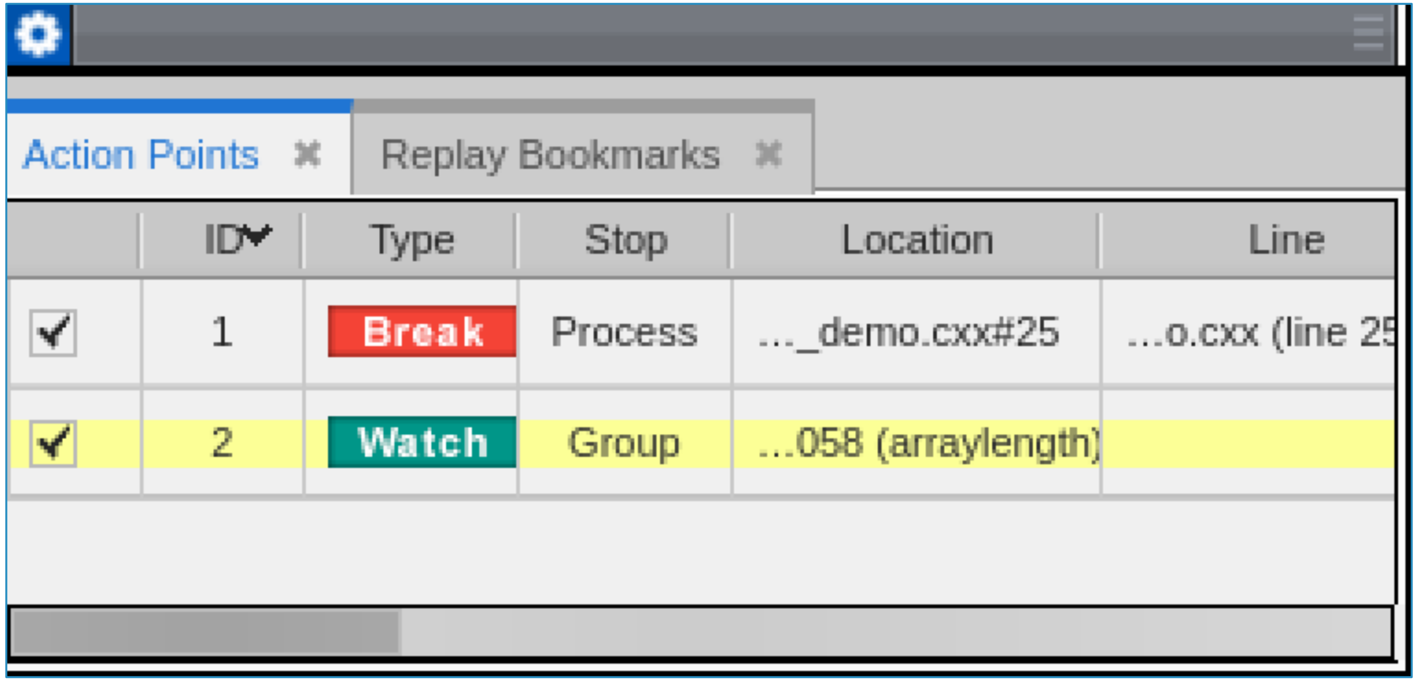


Demo

- TotalView UI demo (QT Threads Example)

Action Points

Action Points



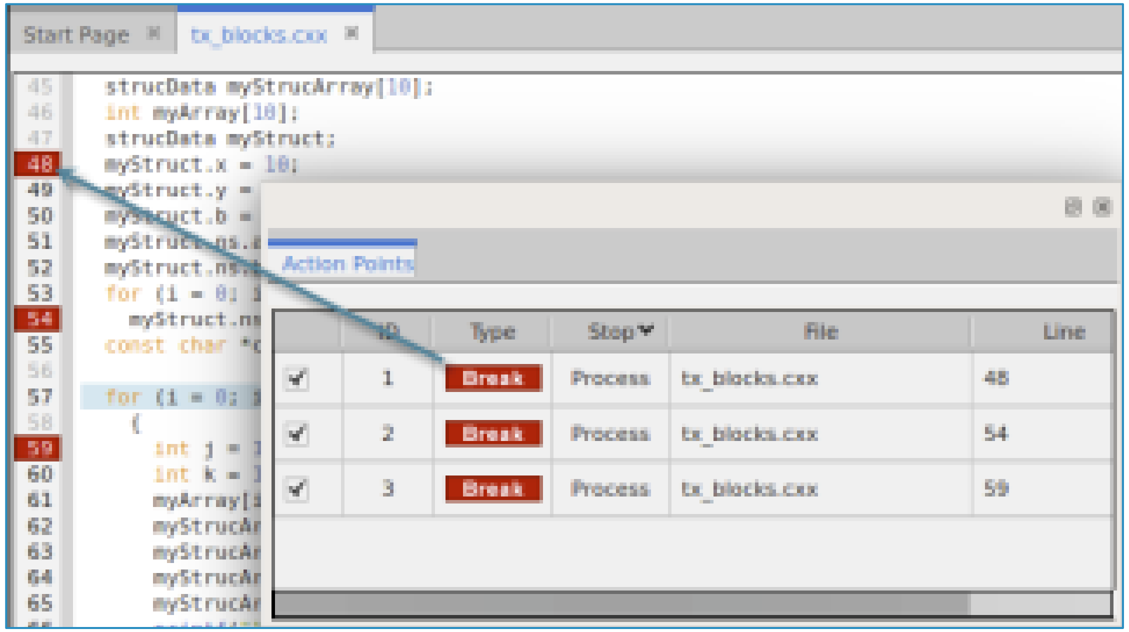
Breakpoint

Evalpoint

Watchpoint

Barrierpoint

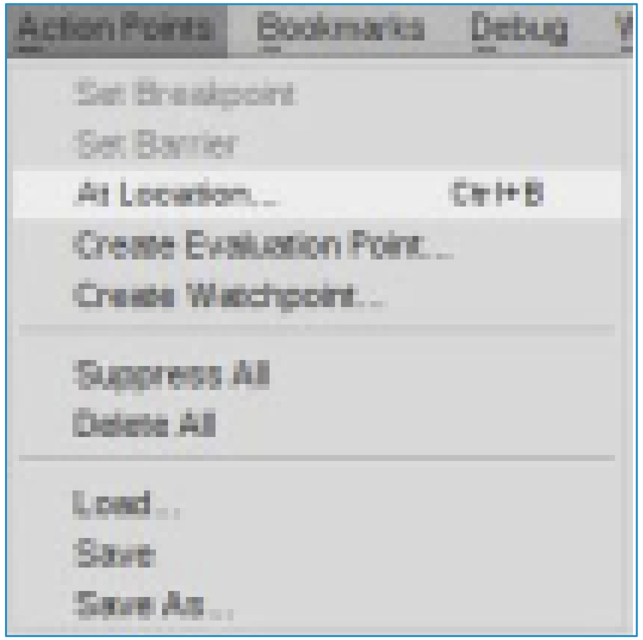
Setting Breakpoints

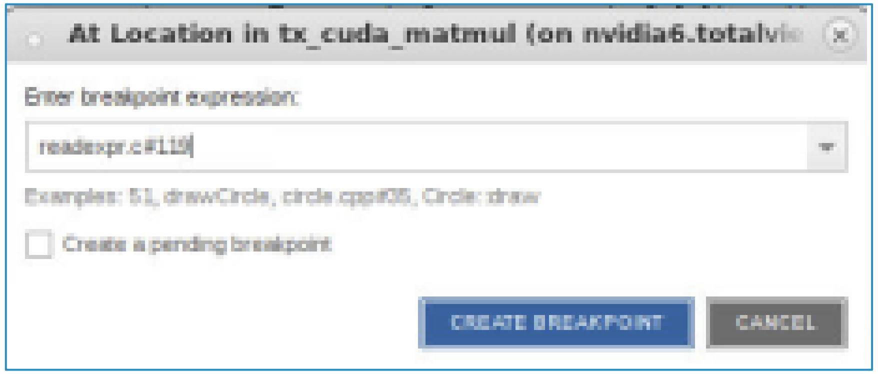


- Setting action points
  - Single-click line number
  - Right clicking on the line number and using the context menu
  - Clicking a line in the source view then selecting the Action Points -> Set breakpoint menu option

Setting Breakpoints

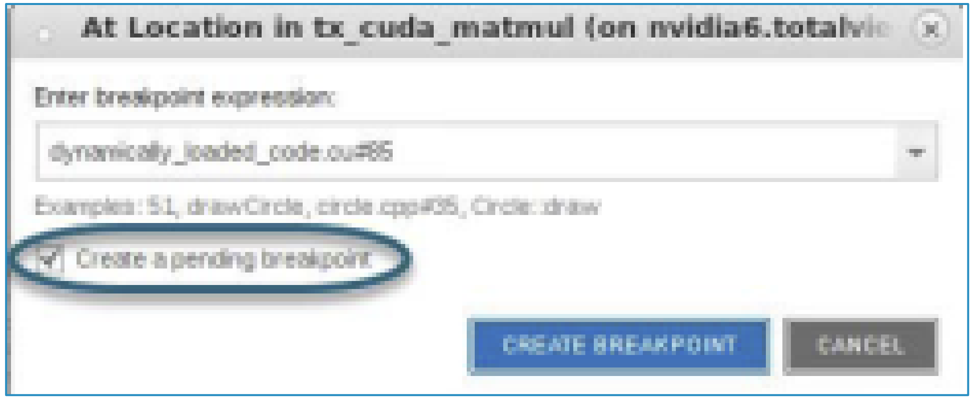
- Breakpoint->At Location…
    - Specify function name or line number
    - If function name, TotalView sets a breakpoint at first executable line in the function



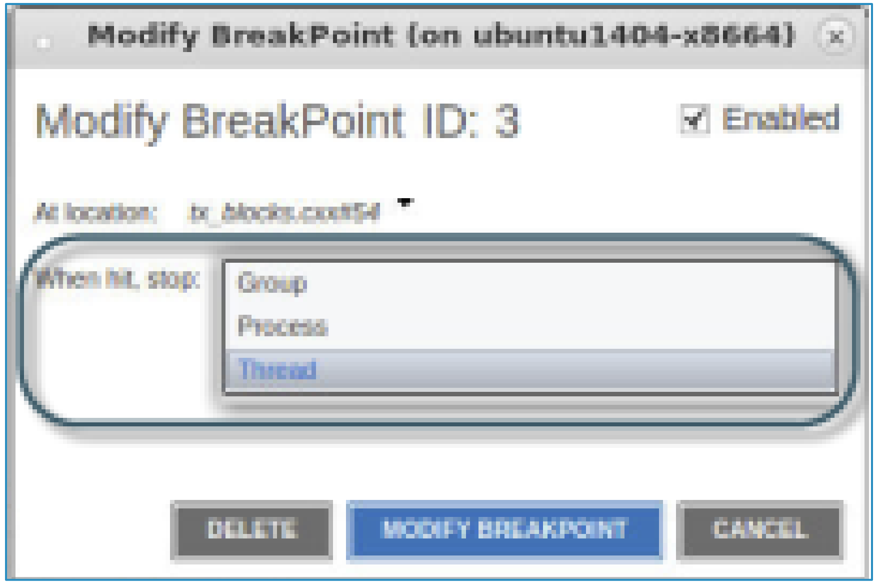


Pending Breakpoints

- Useful when setting a breakpoint on a library that has not yet been loaded into memory



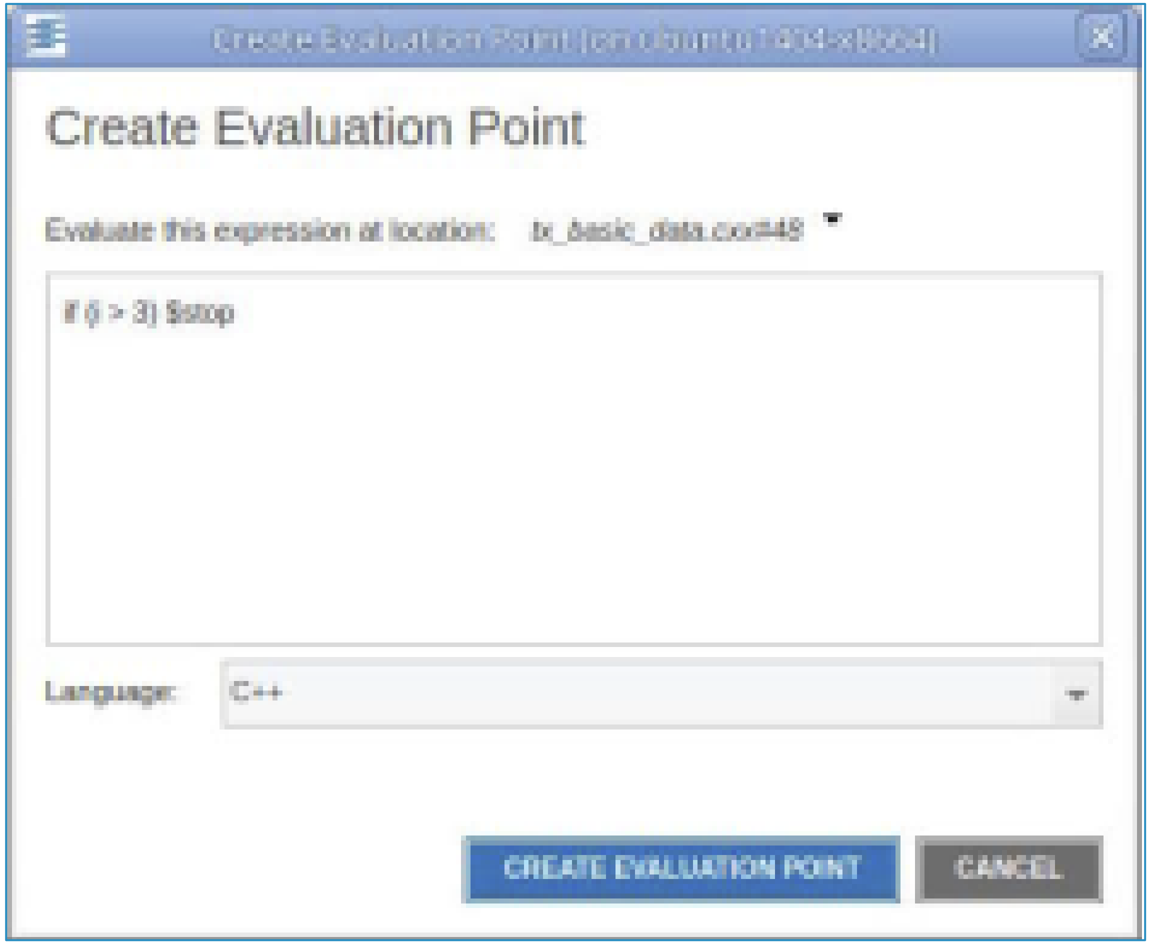
Modifying Breakpoints



- Enable / Disable / Delete a breakpoint
- Adjust the breakpoints width

- **Group**: Stops all running threads in all processes in the group.
- **Process**: Stops all the running threads in the process containing the thread that hit the breakpoint
- **Thread**: Stops only the thread that first executes to this breakpoint

Evalpoints


Create Evaluation Point
Evaluate this expression at location:
tx_basic_data.cxx#48
if (i > 3) $stop
Language:
C++
CREATE EVALUATION POINT
CANCEL

Evalpoints

- Use Eval points to :
  - Include instructions that stop a process and its relatives
  - Test potential fixes or patches for your program
  - Include a goto for C or Fortran that transfers control to a line number in your program
  - Execute a TotalView function
  - Set the values of your program's variables

Evalpoints Examples

- Print the value of a variable to the command line

```
printf("The value of result is %d\n", result);
```

- Skip some code

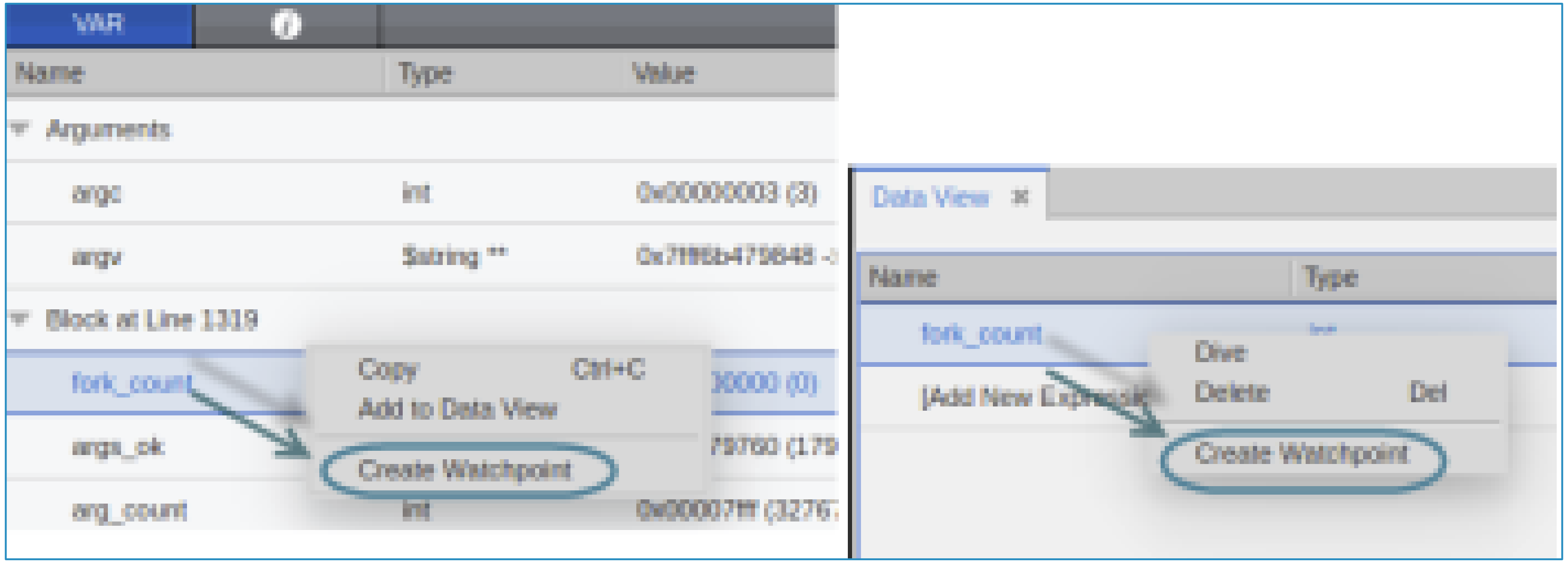
```
goto 63;
```

- Stop a loop after a certain number of iterations

```
if ( (i % 100) == 0)
{
        printf("The value of i is %d\n", i);
        $stop;
};
```

Watchpoints

- Watchpoints are set on a specific memory location
- Execution is stopped when the value stored in that memory location changes
- A breakpoint stops ***before*** an instruction executes. A watchpoint stops ***after*** an instruction executes



Using Watchpoint Expressions

- TotalView has two variables that are used exclusively with watchpoint expressions:
  - $oldval: The value of the memory locations before a change is made.
  - $newval: The value of the memory locations after a change is made.

- Example 1

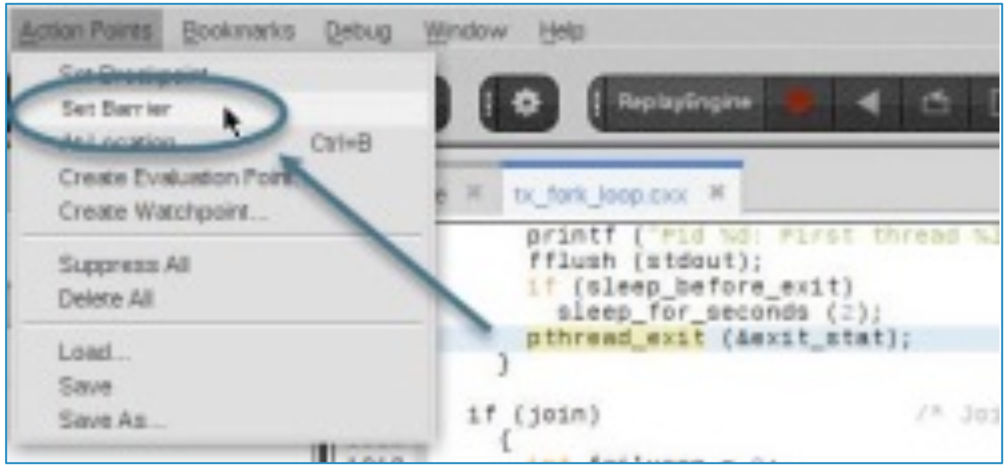
```
if (iValue != 42 && iValue != 44) {
iNewValue = $newval; iOldValue = $oldval; $stop;}
```

- Example 2

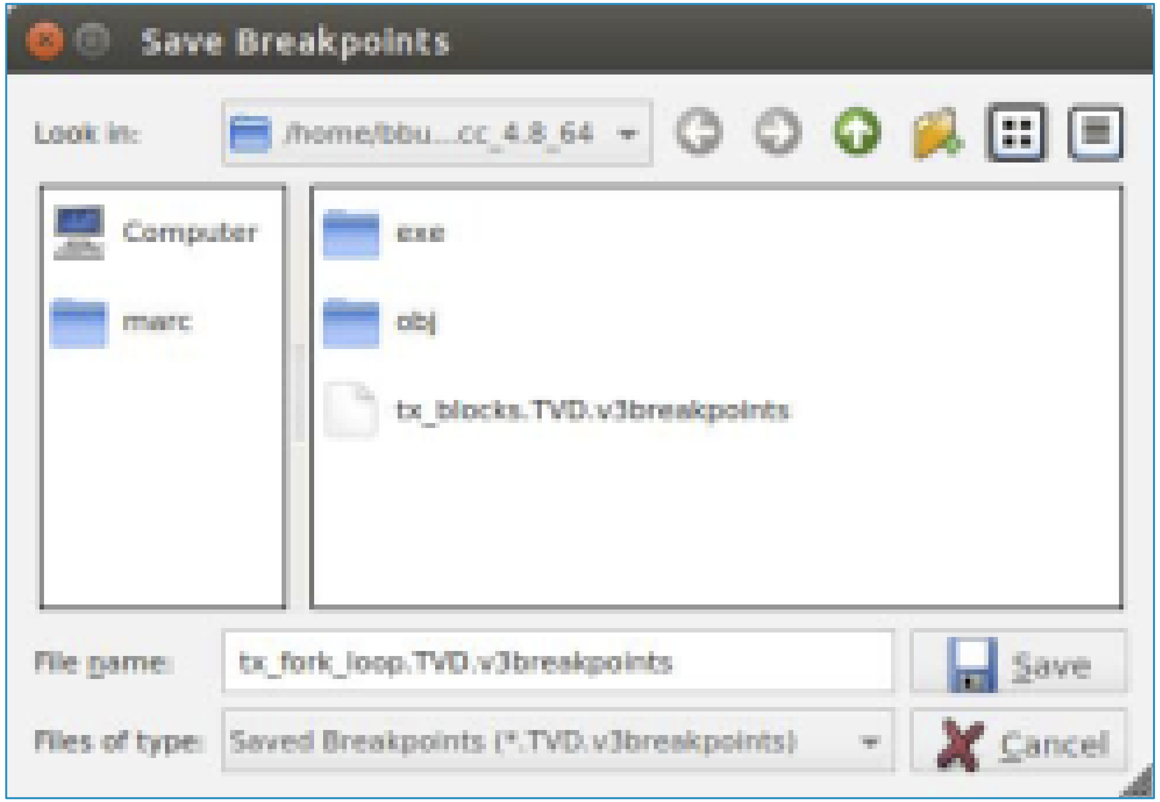
```
if ($oldval >= 0 && $newval < 0) $stop
```

Barrier Breakpoints

- Used to synchronize a group of threads or processes defined in the action point
- Threads or processes are held at barrierpoint until all threads or processes in the group arrive
- When all threads or processes arrive the barrier is satisfied and the threads or processes are released



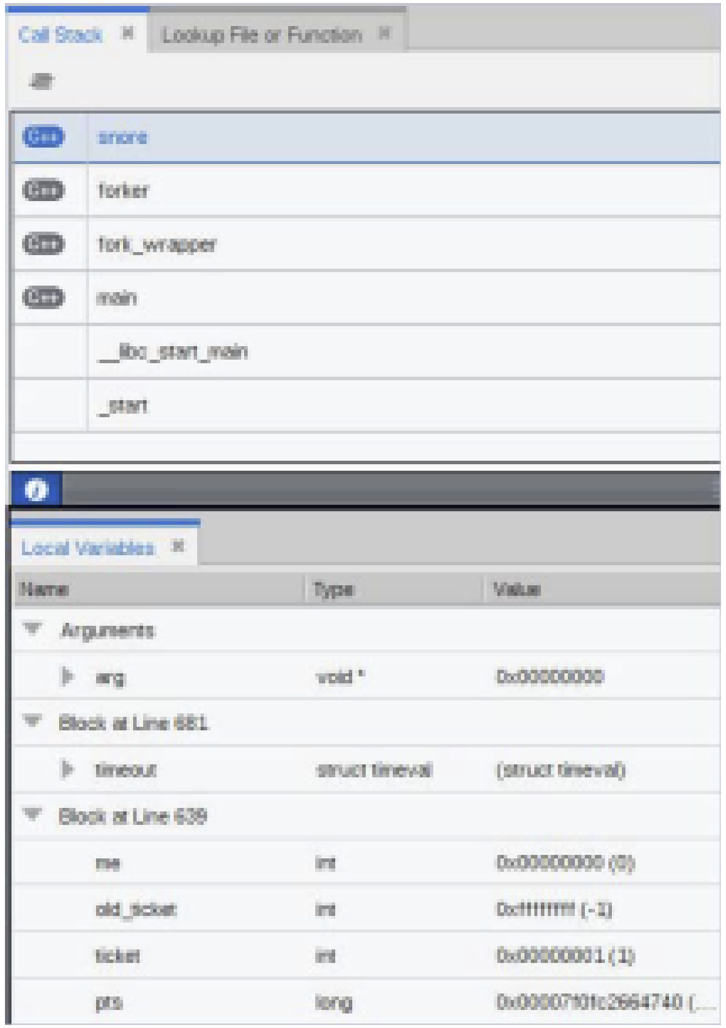
Saving Breakpoints



From the Action Points menu select Save or Save As to save breakpoints
Turn on option to save action points on exit

Examining and Editing Data

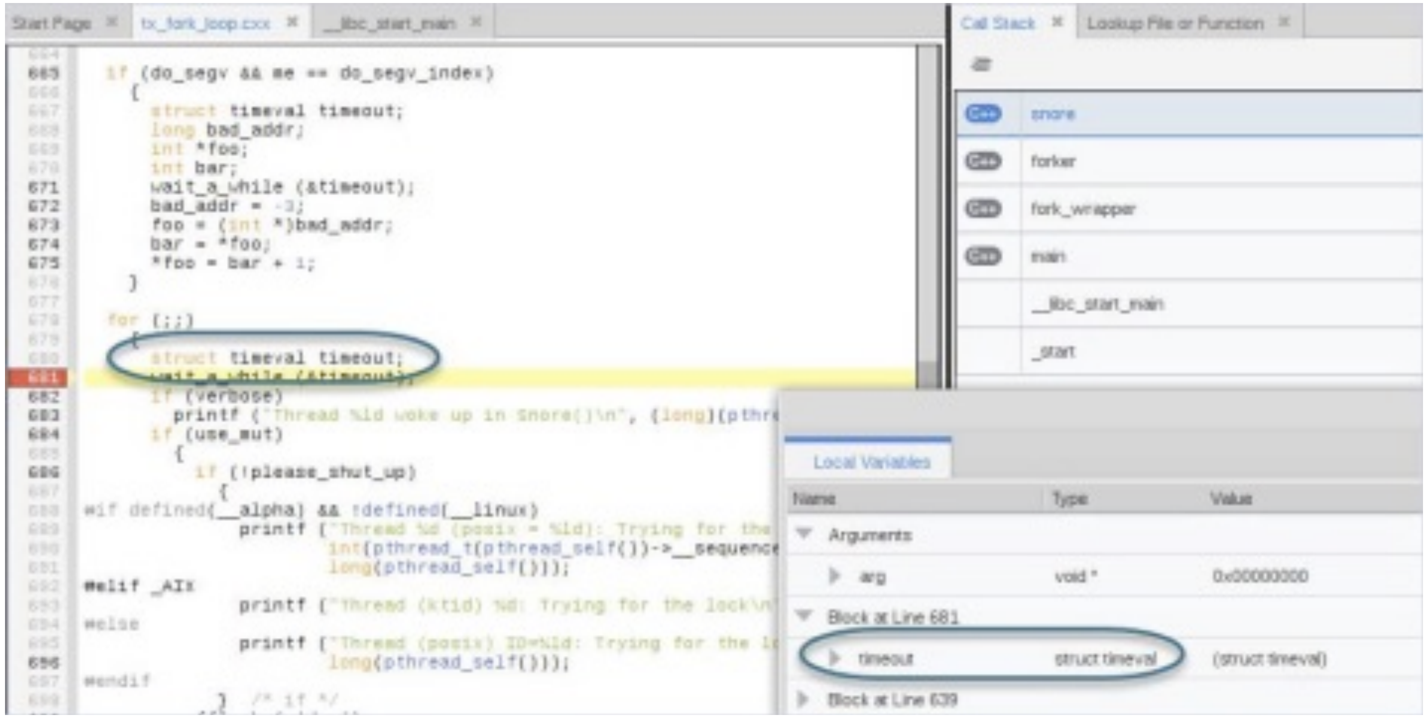
Call Stack and Local Variables



The Call Stack View consists of two panels :

- The Call Stack panel
- The Local Variables panel

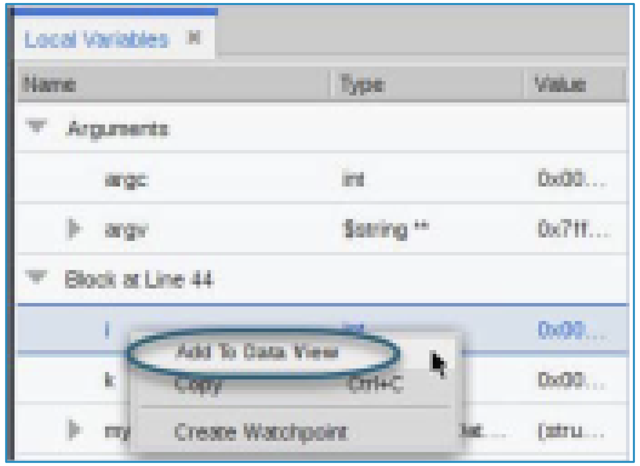
The Local Variables Panel



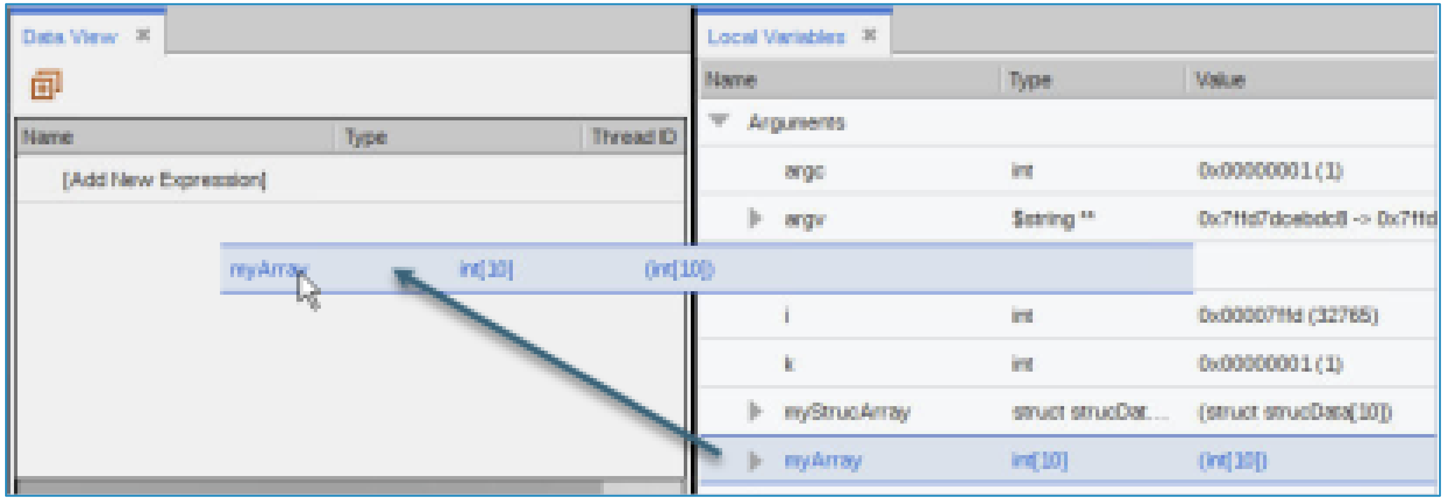
The Local Variables panel displays variables for the thread of interest (TOI)

The Data View Panel

Add data to the Data View using the context menu or by dragging and dropping



Context menu

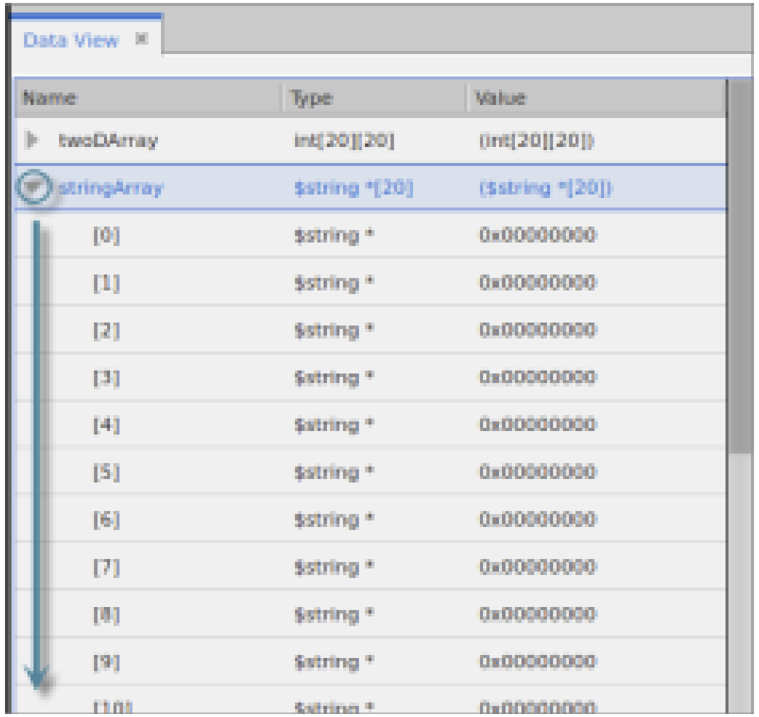


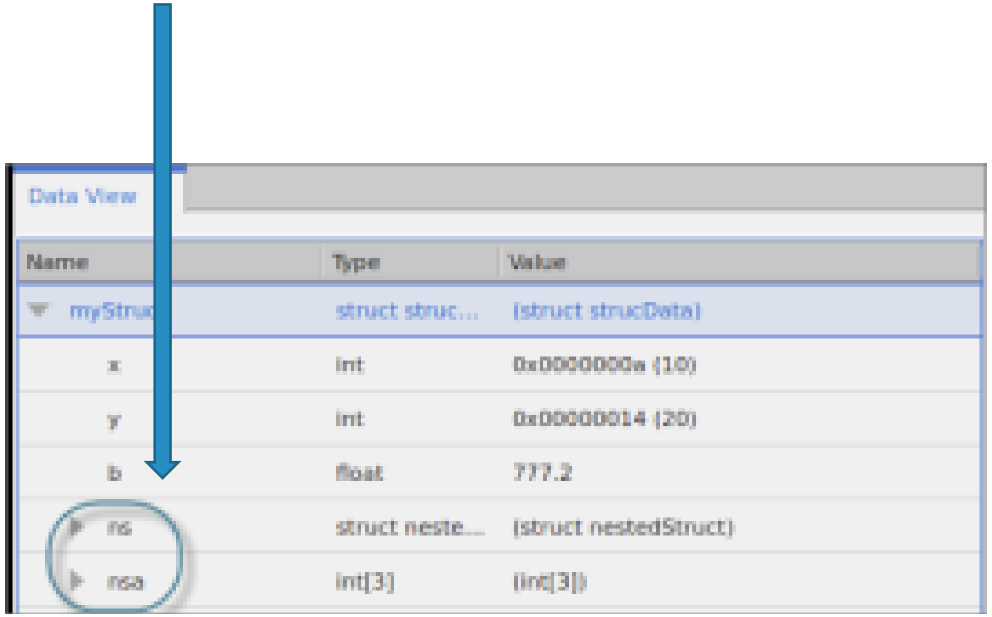
Drag and drop

The Data View Panel

Select the right arrow to display the substructures in a complex variable

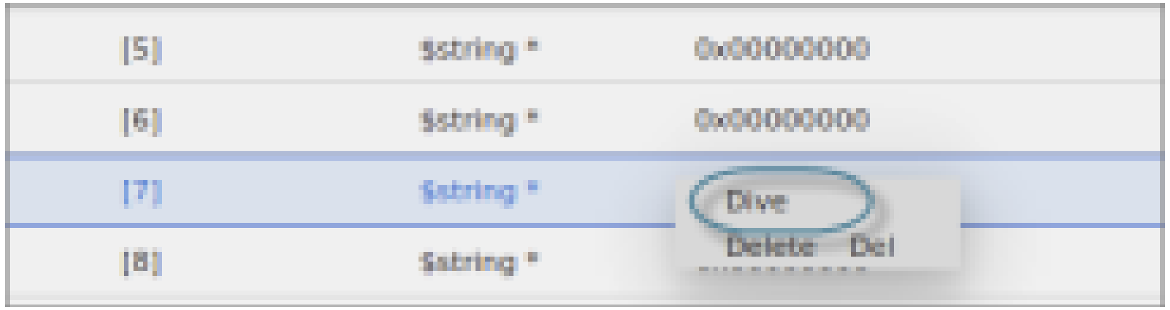
Any nested structures are displayed in the data view

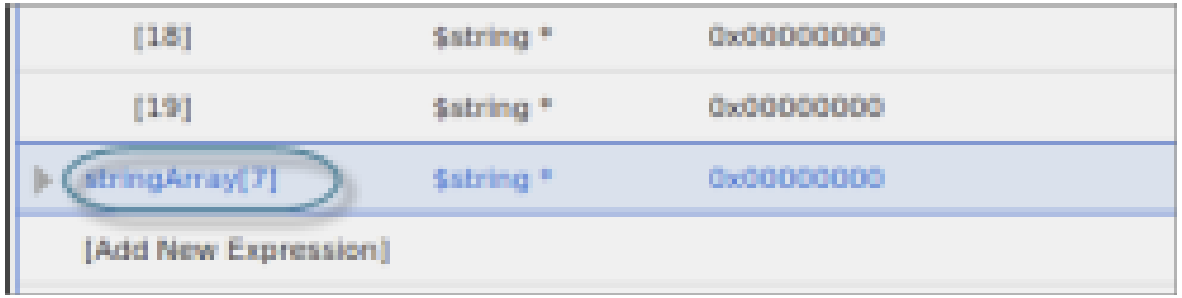




The Data View Panel

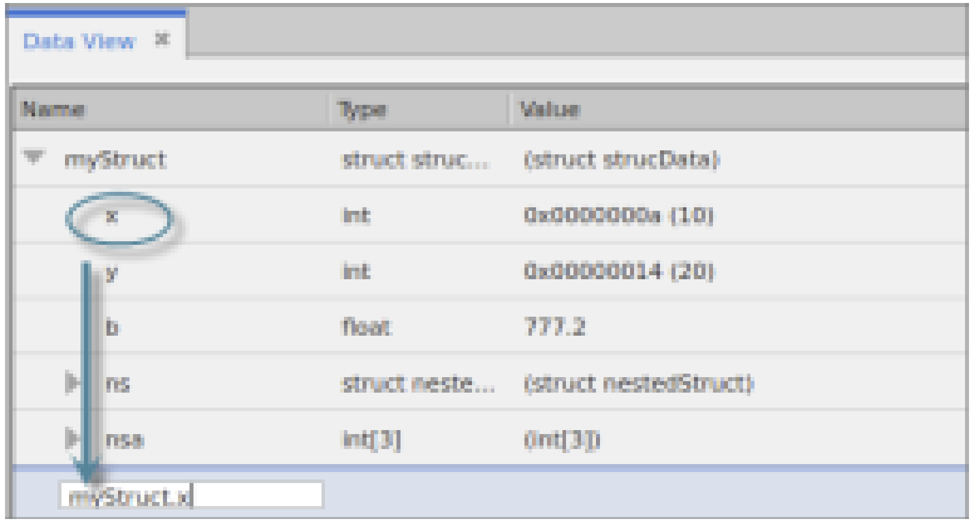
Dive on a single element to view individual data in the Data View





The Data View Panel

Enter a new expression in the Data View panel to view that data



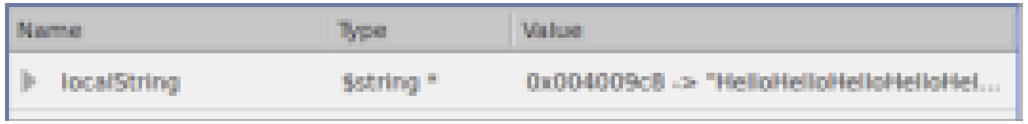
Type the expression in the [Add New expression] field

A new expression is added

Increment a variable

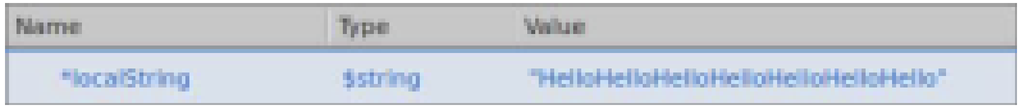
The Data View Panel

Dereferencing a pointer



When you dive on a variable, it is not dereferenced automatically

Double click in the Name column to make it editable and dereference the pointer

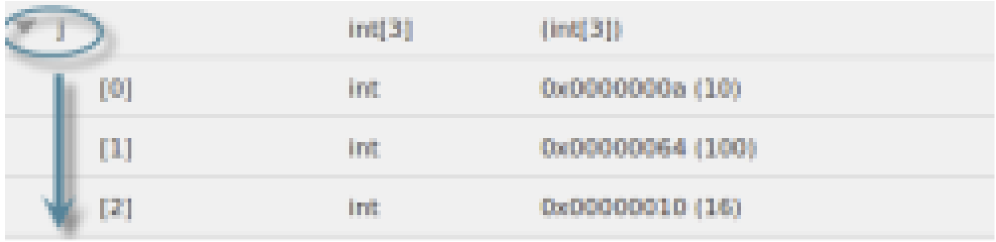


The Data View displays the variables value

The Data View Panel

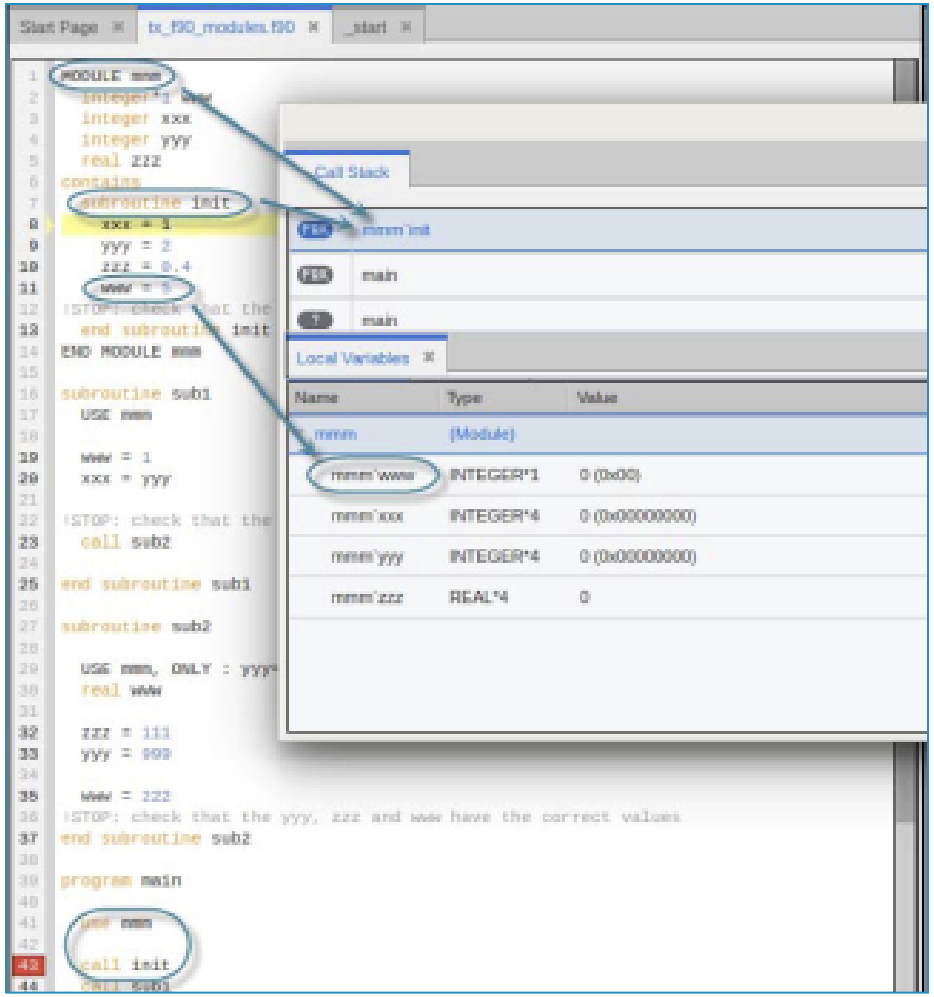
Casting to another type

Cast a variable into an array by adding the array specifier



TotalView displays the array

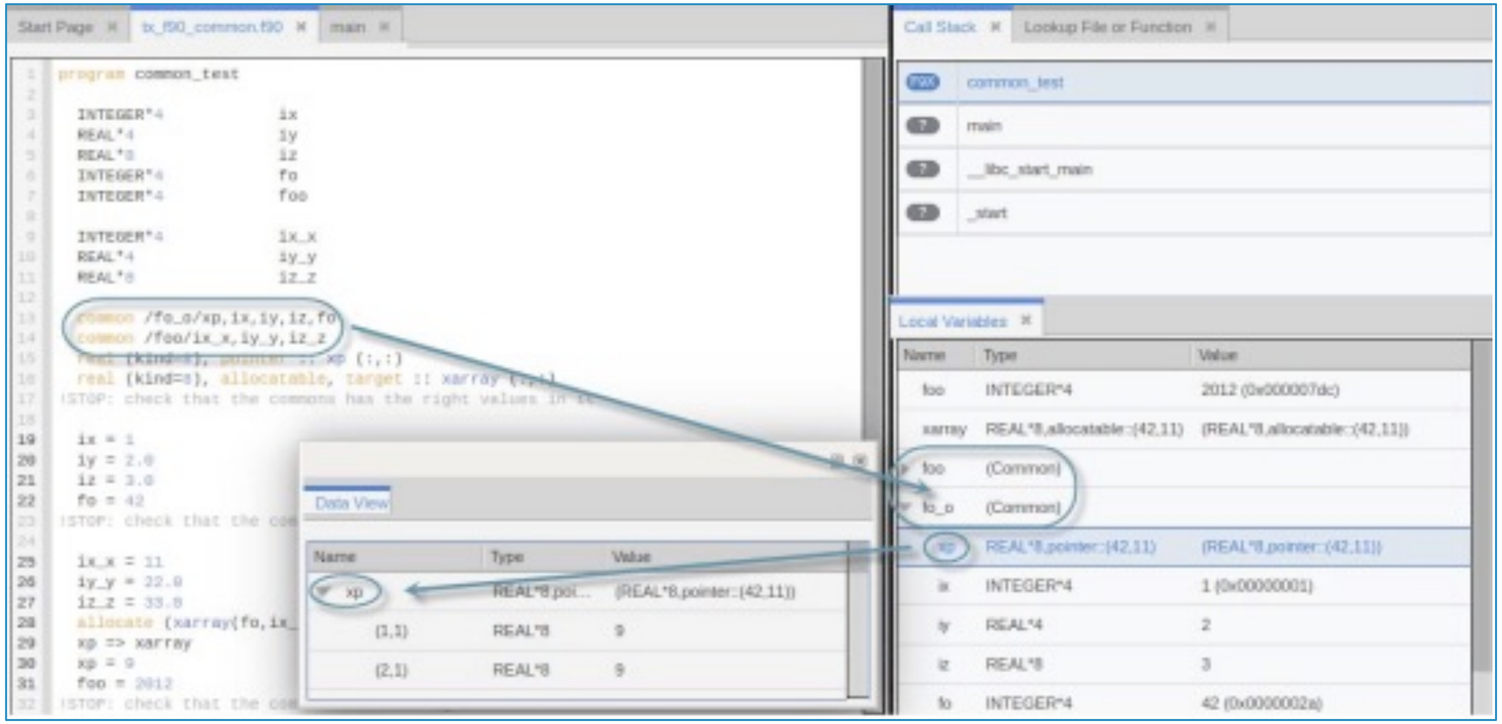
Viewing Data in Fortran



The qualified subroutine name appears in the Call Stack view.

The qualified variable names appear in the Local Variable panel.

Fortran Common Blocks

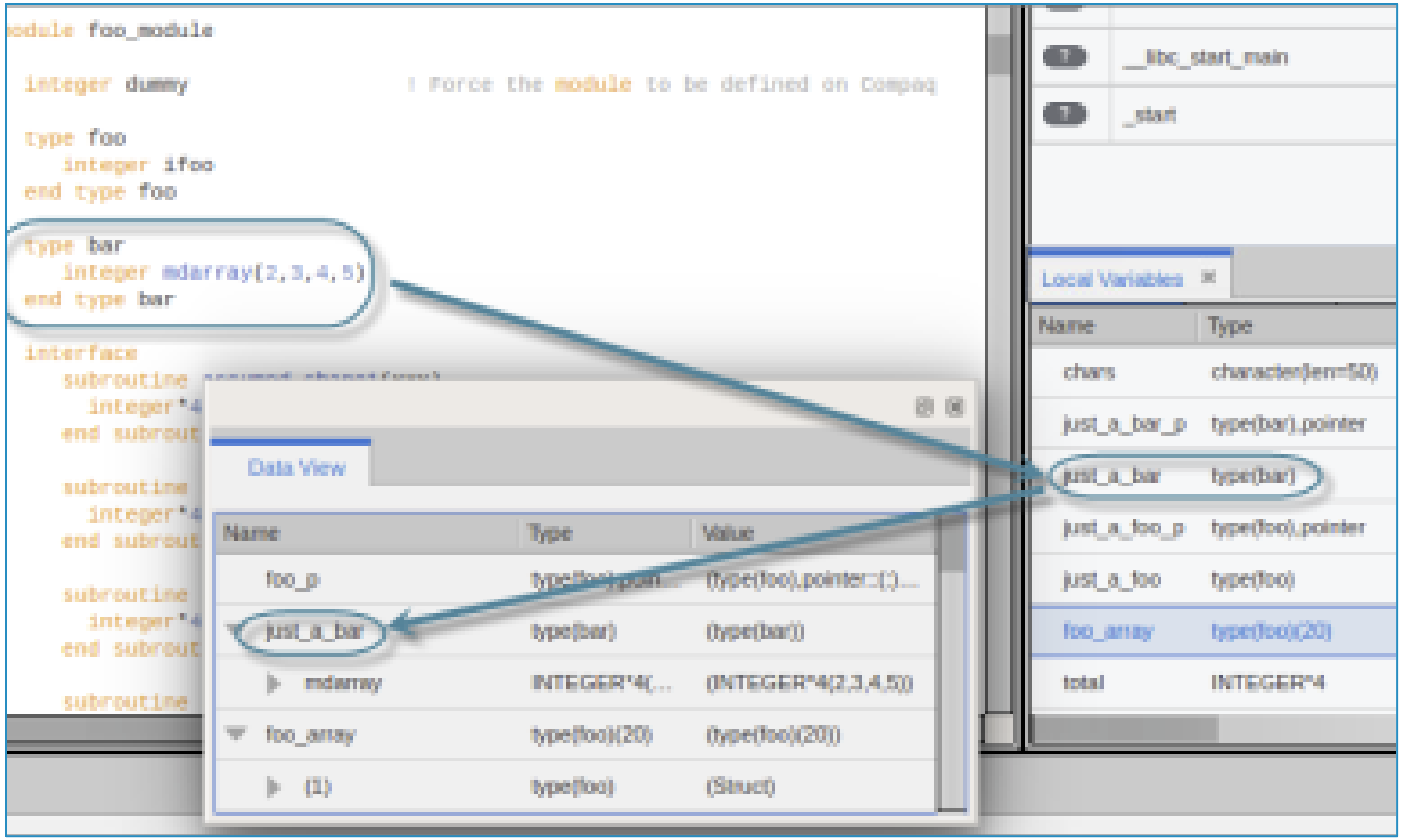


For each common block defined in the scope of a subroutine or function, TotalView creates an entry in that function’s common block list.

The names of common block members have function scope, not global scope.

If you select the function in the Call Stack view, the common blocks and their variables appear in the Local Variables panel.

Fortran User-Defined Types

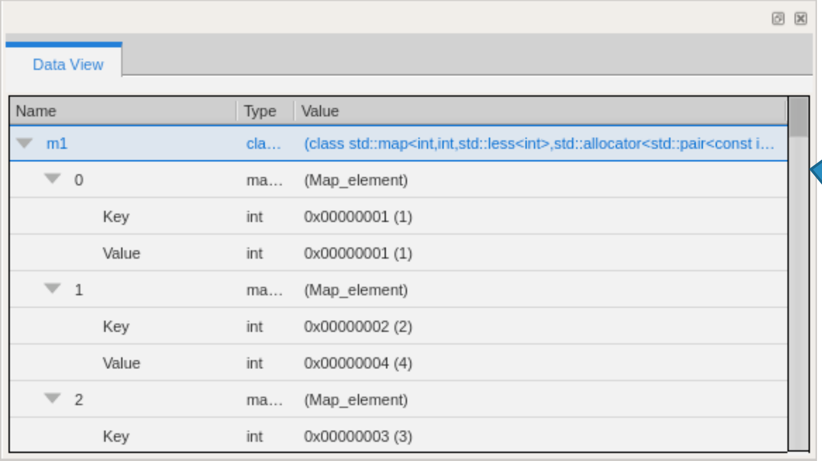


TotalView displays user-defined types in the Local Variables panel, which you can then add to the Data View for more detail

Advanced C++ and Data Debugging

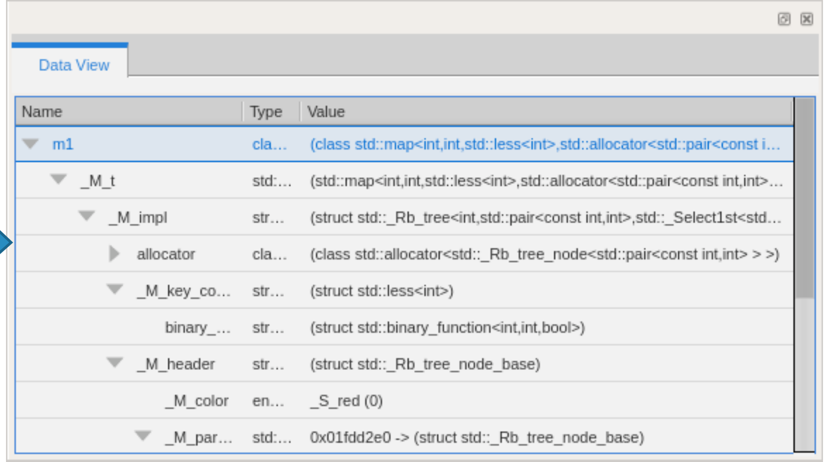
C++ Container Transformations

- TotalView transforms many of the C++ and STL containers including:
  - array, forward_list, tuple, map, set, vector and others.



See This!

Instead of This



Advanced C++ Support

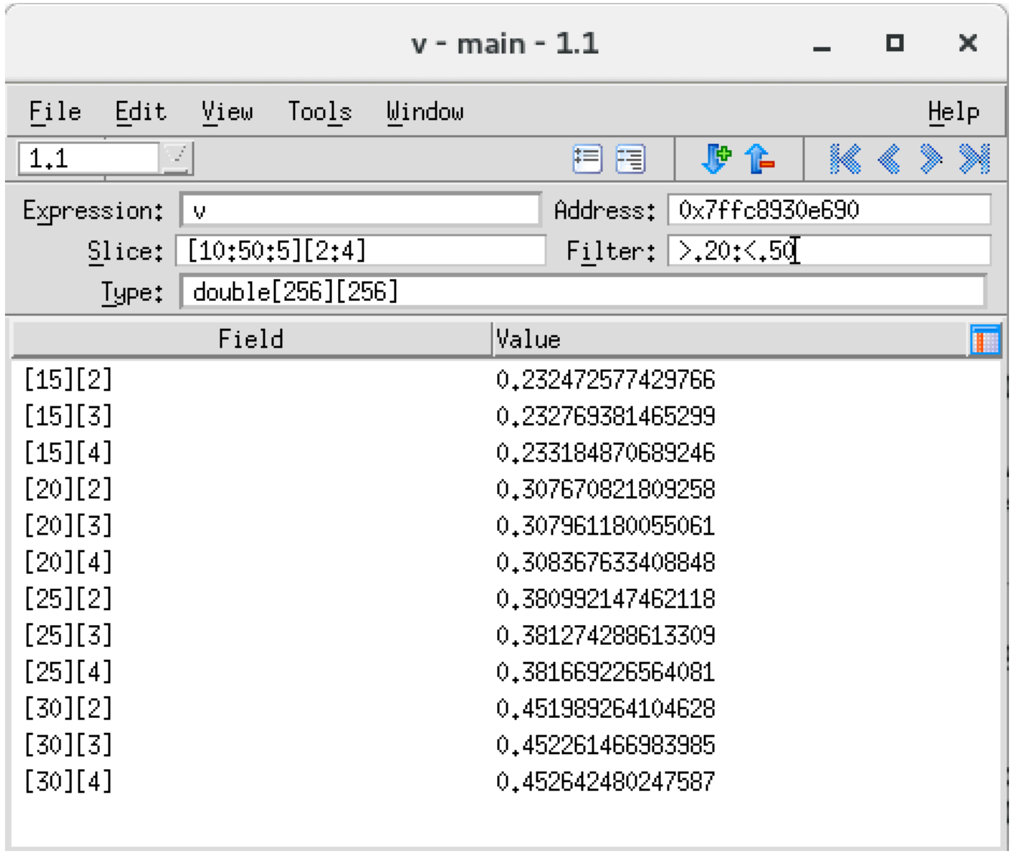
- TotalView supports debugging the latest C++11/14/17 features including:
  - lambdas, transformations for smart pointers, auto types, R-Value references, range-based loops, strongly-typed enums, initializer lists, user defined literals

```
#include <functional>
#include <vector>
#include <iostream>
double eval(std::function<double(double)> f, double x = 2.0){
  return f(x);}

int main(){
//   // One line lambdas
   auto glambda1 = [](int a, float b) { return a < b; };
   // Two line lambda
   auto glambda2 = [](int a, float && b) {
     if (a < b)
     return 1;
     if (b>a)
     return -1;
     return 0;
   };

   bool b = glambda1(3, 3.14);
   int i = glambda2(3, 3.14);
   for (int i=0; i<10;i++)
     b = glambda1(i, 3.14+i);


   std::function<double(double)> f0    = [](double x){
     return 1;};
   auto                          f1    = [](double x){
     return x;};
   decltype(f0)                  fa[3] = {f0,f1,[](double x){
```

Array Slicing, Striding and Filtering

- Slicing – reduce display to a portion of the array
    - [lower_bound:upper_bound]
    - [5:10]
- Striding – Skip over elements
    - [::stride]
    - [::5], [5:10:-1]
- Filtering
    - Comparison: ==, !=, <, <=, >, >=
    - Range of values: [**>**] *low-value* **:** [**<**] *high-value*
    - IEEE values: $nan, $inf, $denorm

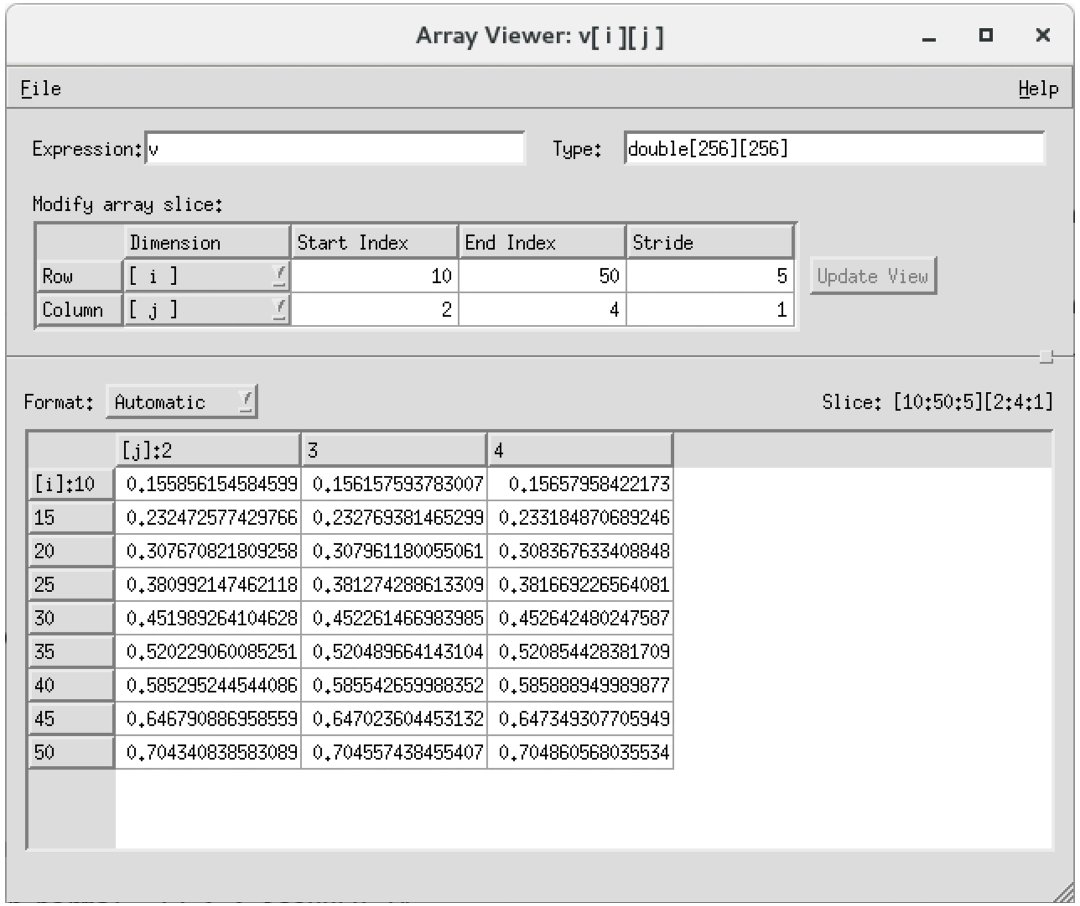
Classic UI Only



Viewing Array Data

- Easily view 2D array data in table format.

Classic UI Only



	[j]:2	3	4
[i]:10	0.155856154584599	0.156157593783007	0.15657958422173
15	0.232472577429766	0.232769381465299	0.233184870689246
20	0.307670821809258	0.307961180055061	0.308367633408848
25	0.380992147462118	0.381274288613309	0.381669226564081
30	0.451989264104628	0.452261466983985	0.452642480247587
35	0.520229060085251	0.520489664143104	0.520854428381709
40	0.585295244544086	0.585542659988352	0.585888949989877
45	0.646790886958559	0.647023604453132	0.647349307705949
50	0.704340838583089	0.704557438455407	0.704860568035534

Array Statistics

- Easily display a set of statistics for the filtered portion of your array

Start Page ✖ combined.cxx ✖ vol ✖

Array: vol (Thread: 1.1) UPDATE

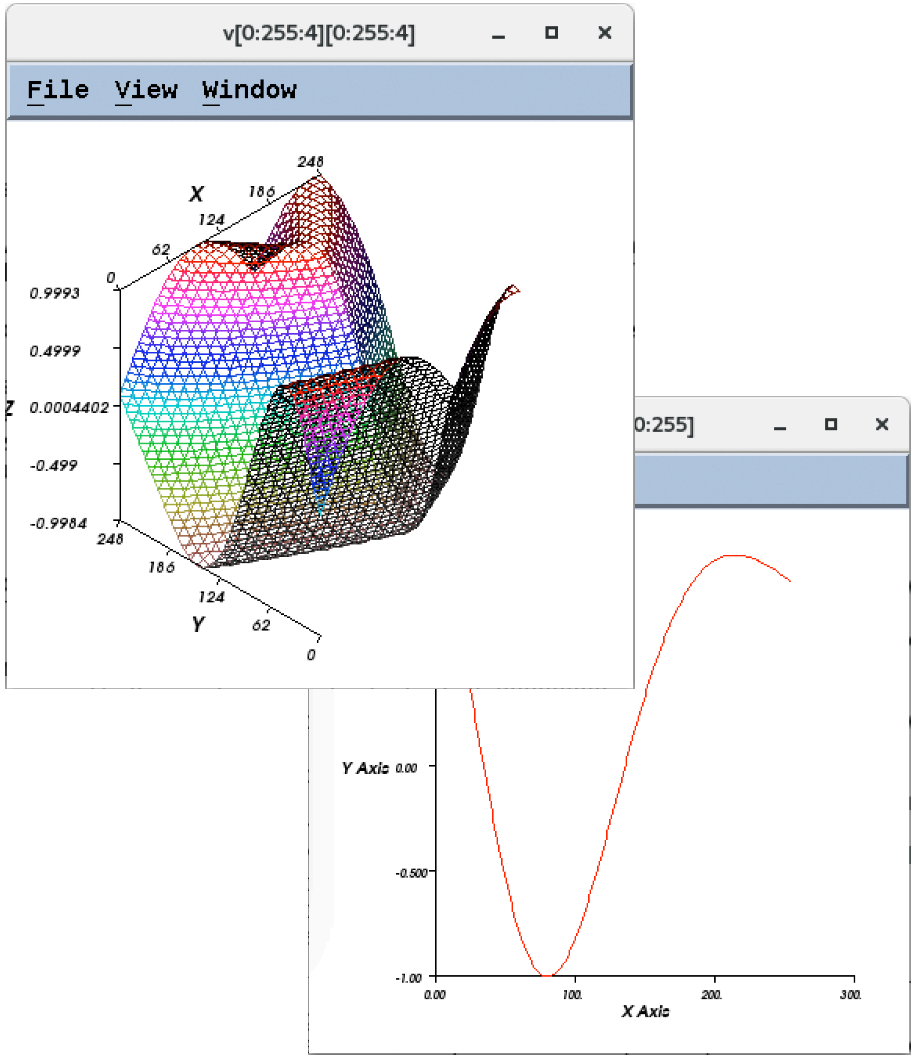
Slice: [:][:] Type: double[20][20]

Statistic	Value
Count	400
Zero Count	0
Sum	597909.794
Minimum	6.28304
Maximum	7273.40418
Median	915.75308
Mean	1494.774485
Standard Deviation	1566.23066267959
First Quartile	283.91487
Third Quartile	2259.14557
Lower Adjacent Value	6.28304
Upper Adjacent Value	5195.2887
Nan Count	0
Infinity Count	0
Denormalized Count	0
Checksum	45976

Visualizing Array Data

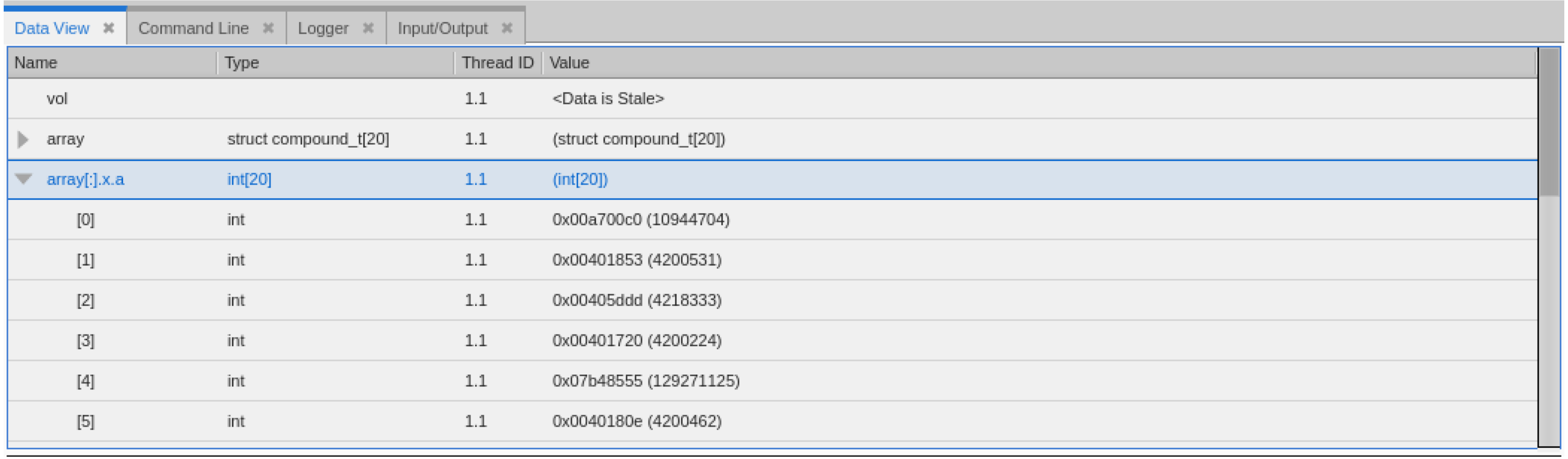
Classic UI Only

- Visualizer creates graphic images of your program's array data.
- Visualize one or two dimensional arrays
- View data manually through the Window > Visualize command on the Data Window
- Visualize data programmatically using the $visualize function



Dive in All

- Dive in All
  - Use Dive in All to easily see each member of a data structure from an array of structures



Q&A

Break

Python Debugging

Python in HPC

- Python development trends:
  - Increased usage of Python to build applications that call out to C++
  - Provides access to
    - High-performance routines
    - Leverage existing algorithms and libraries
    - Utilize advanced multi-threaded capabilities
  - Calling between languages easily enabled using technologies such as **SWIG**, **ctypes**, **Pybind**, Cython, CFFI, etc
  - Debugging mixed language applications is not easy

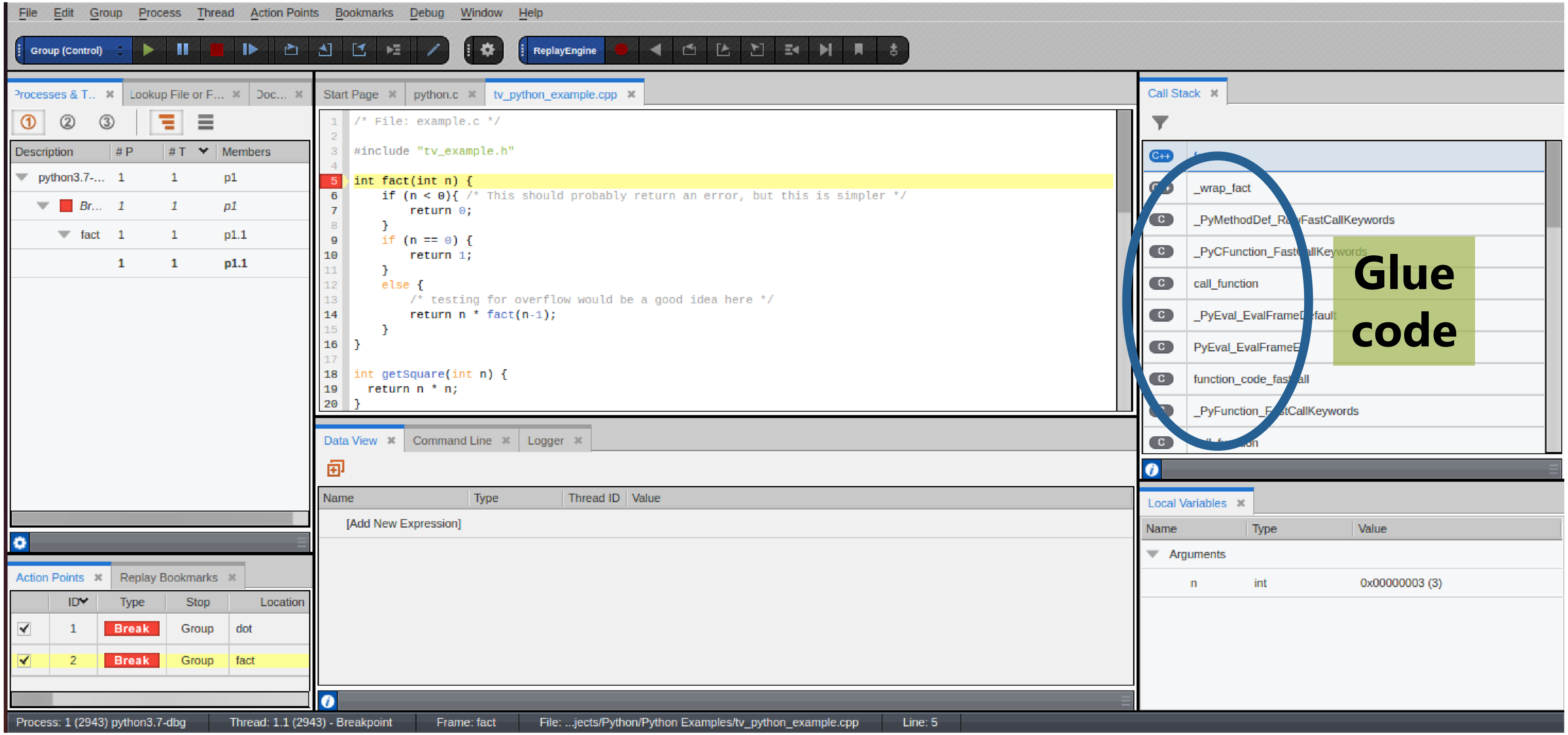
Python debugging with TotalView

- Debugging one language is difficult enough
- Understanding the flow of execution across language barriers is hard
- Examining and comparing data in both languages is challenging

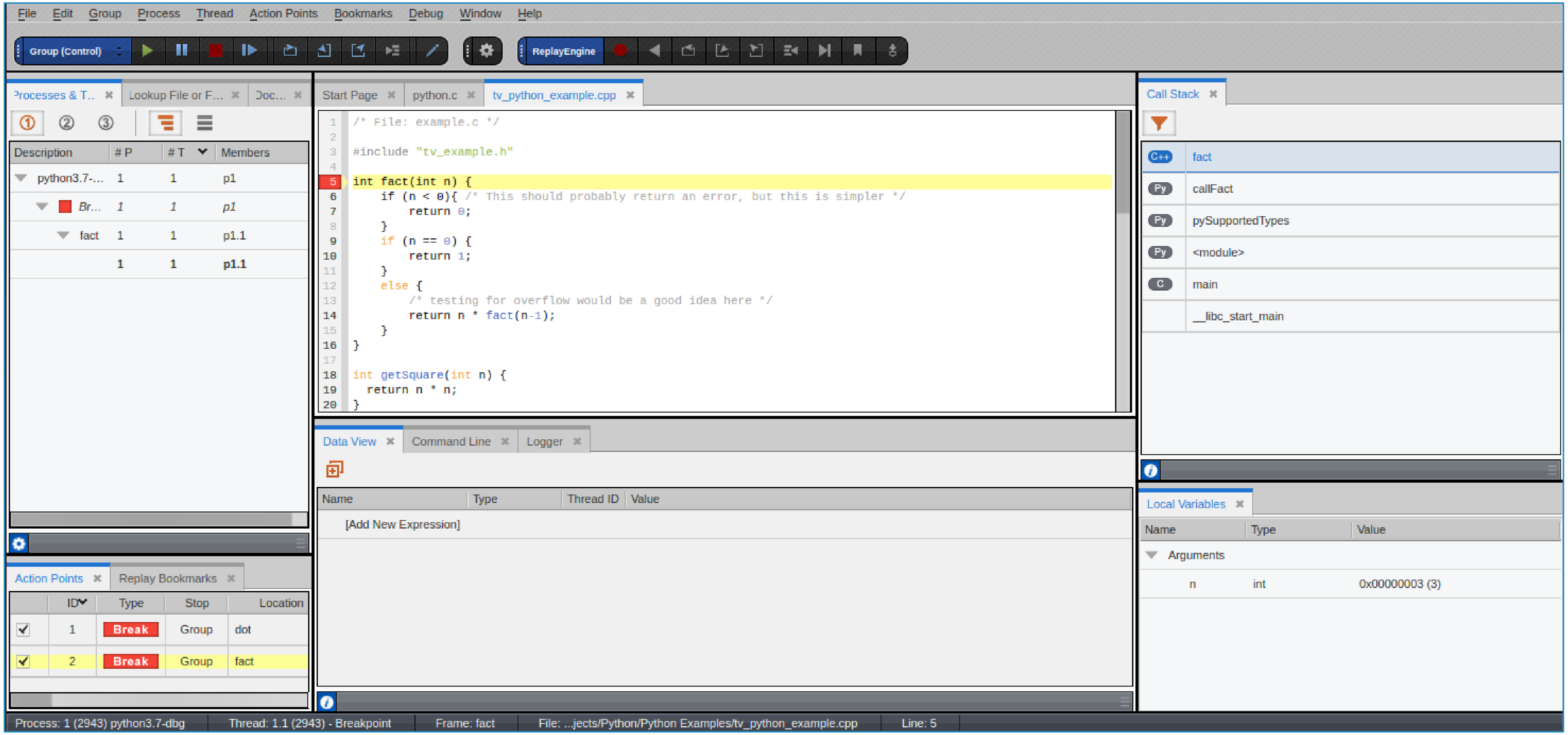
- What TotalView provides:
  - Easy python debugging session setup
  - Fully integrated Python and C/C++ call stack
  - ”Glue” layers between the languages removed
  - Easily examine and compare variables in Python and C++
  - Modest system requirements
  - Utilize reverse debugging and memory debugging
  - Support for Python 2.7 and Python 3.0

- What TotalView does not provide (yet):
  - Setting breakpoints and stepping within Python code

Python without Filtering



Python with filtering



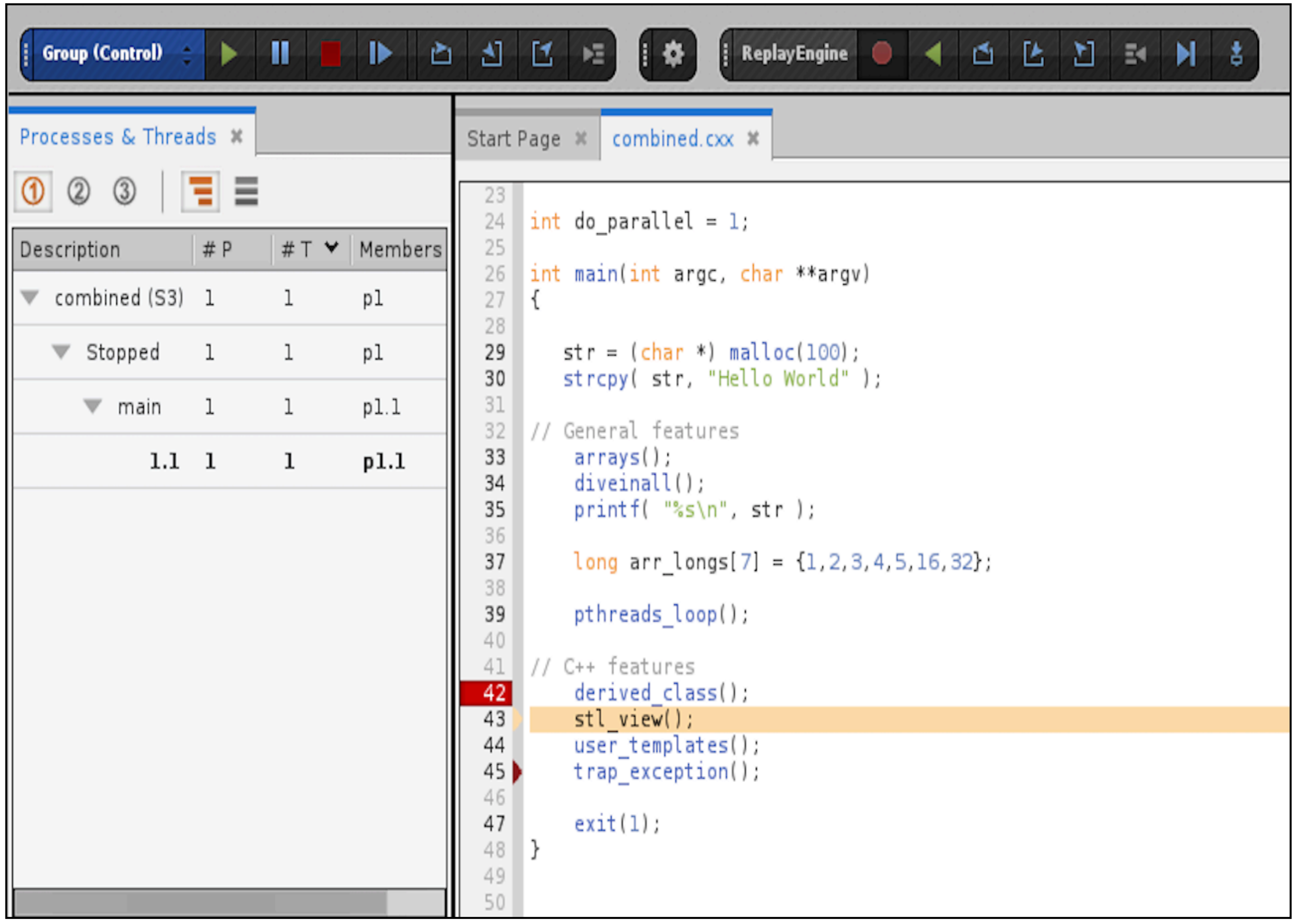
Demo

- TotalView Python / C++ debugging demo (test_python_types.py)

Reverse Debugging with Replay Engine

Reverse debugging

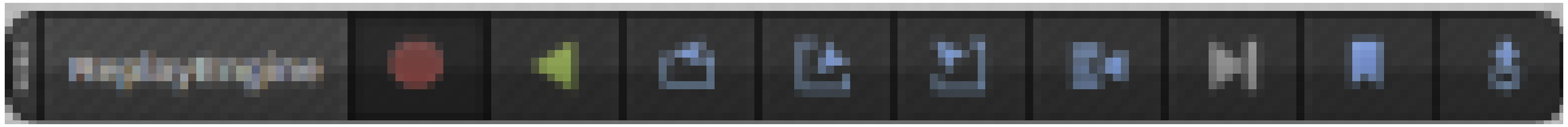
- How do you isolate an intermittent failure?
  - Without TotalView
    - Set a breakpoint in code
    - Realize you ran past the problem
    - Re-load
    - Set breakpoint earlier
    - Hope it fails
    - Keep repeating
  - With TotalView
    - Set a breakpoint
    - Start recording
    - See failure
    - Run backwards/forwards in context of failing execution
  - Reverse Debugging
    - Re-creates the context when going backwards
    - Focus down to a specific problem area easily
    - Saves days in recreating a failure



Recording and Playback

- When ReplayEngine is saving state information, it is in **Record Mode**
- The saved state information is the program's execution history
- You can save the execution history at any time and reload the recording when debugging the executable in a subsequent session
- Using a ReplayEngine command, ether from the Toolbar or the CLI, shifts ReplayEngine into **ReplayMode**
- Debugging commands that do not work in ReplayMode include:
    - Changing a variable's value
    - Functions that alter memory
    - Running threads asynchronously

ReplayEngine Toolbar



Record a toggle that enables and disables ReplayEngine.

Go Back displays the state that existed at the last action point. If no action point is encountered, ReplayEngine displays the state that existed at the start of its recorded history.

Prev displays the state that existed when the previous statement executed. If that line had a function call, Prev skips over the call.

Unstep displays the state that existed when the previous statement executed. If that line had a function call, ReplayEngine moves to the last statement in that function.

Caller displays the state that existed before the current routine was called.

Back To displays the program's state for the line you select. This line must have executed prior to the currently displayed line.

Live shifts from replay mode to record mode. It also displays the statement that would have executed had you not moved into ReplayMode.

Bookmark creates a ReplayEngine bookmark at a selected location.

Save saves the current replay recording session to a file.

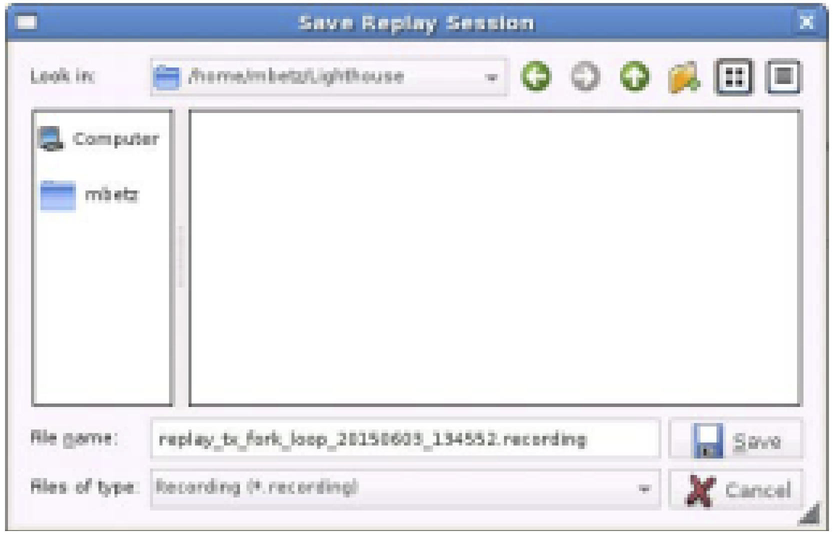
Saving and Loading Execution History

- TotalView can save the current ReplayEngine execution history to file at any time

- The saved recording can be loaded into TotalView using any of the following:
  - At startup, using the same syntax as when opening a core file:

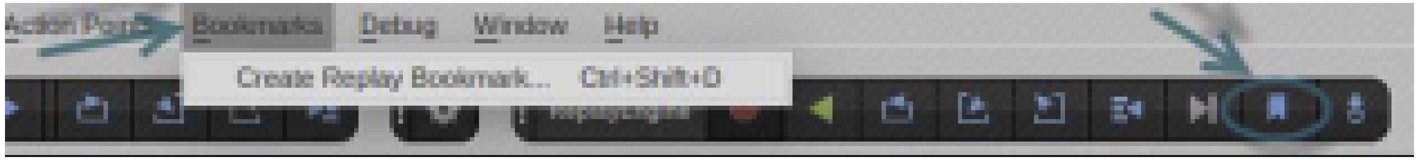
    totalview -newUI *executable recording-file*

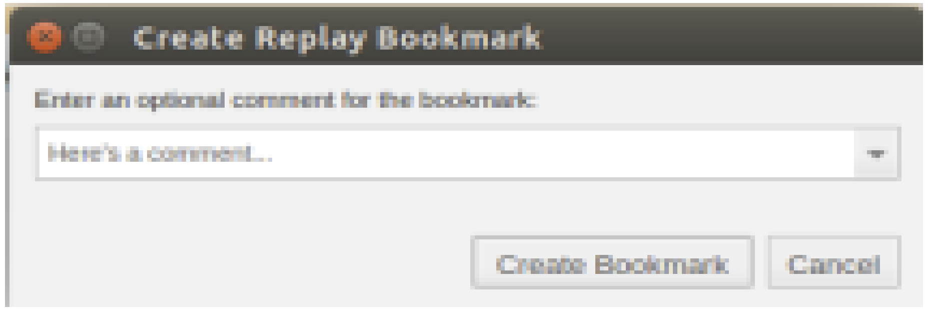
  - On the Start Page view by selecting Load Core File or Replay Recording File



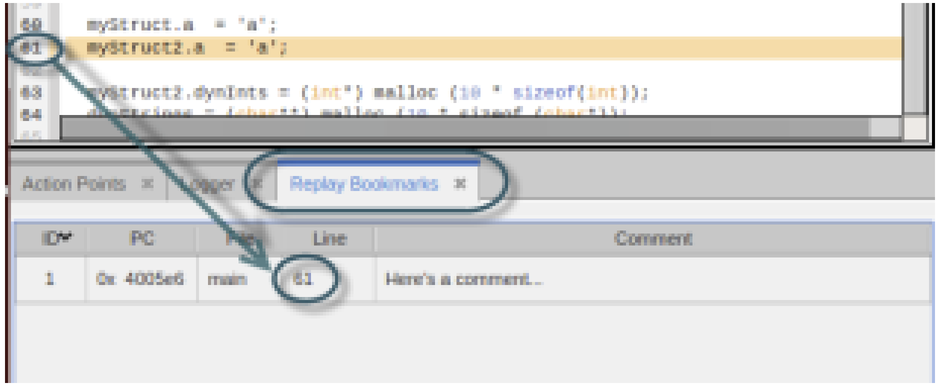
Replay Bookmarks

- Replay bookmarks mark a point in the execution of a program, allowing you to quickly jump back to that point in time





Creating a Replay Bookmark



Activating a Replay Bookmark

Setting Preferences for ReplayEngine

- You can set the following preferences for ReplayEngine
  - the maximum amount of memory to allocate to ReplayEngine
  - The preferred behaviour when the memory limit is reached

- Setting the maximum amount of memory. The default value ‘0’ specifies to limit the maximum size by available memory only.

dset TV::replay_history_size *value*

e.g. dset TV::replay_history_size 1024M

- Setting the preferred behaviour. By default, the oldest history is discarded so that recording can continue

dset TV::replay_history_mode **1** (Discard oldest history and continue recording)

dset TV::replay_history_mode **2** (Stop the process when the buffer is full)

Demo

- TotalView ReplayEngine Demo

Debugging OpenMP Applications

TotalView support for OpenMP

Some of the features TotalView supports:

- Source-level debugging of the original OpenMP code
- The ability to plant breakpoints throughout the OpenMP code, including lines that are executed in parallel
- Visibility of OpenMP worker threads
- Access to SHARED and PRIVATE variables in OpenMP PARALLEL code
- Access to OMP THREADPRIVATE data in code compiled by supported compilers

About TotalView OpenMP Features

- The compiler can generate multiple outlined routines from a single parallel region. This means that a single line of source code can generate multiple blocks of machine code inside different functions
- You can't single step into or out of a parallel region. Instead, set a breakpoint inside the parallel region and let the process run to it. After execution reaches the parallel region, you can single step in it
- OpenMP programs are multi-threaded programs, so the rules for debugging multi-threaded programs apply

Demo

- TotalView OpenMP demo (tx_omp_c_threadprivate)

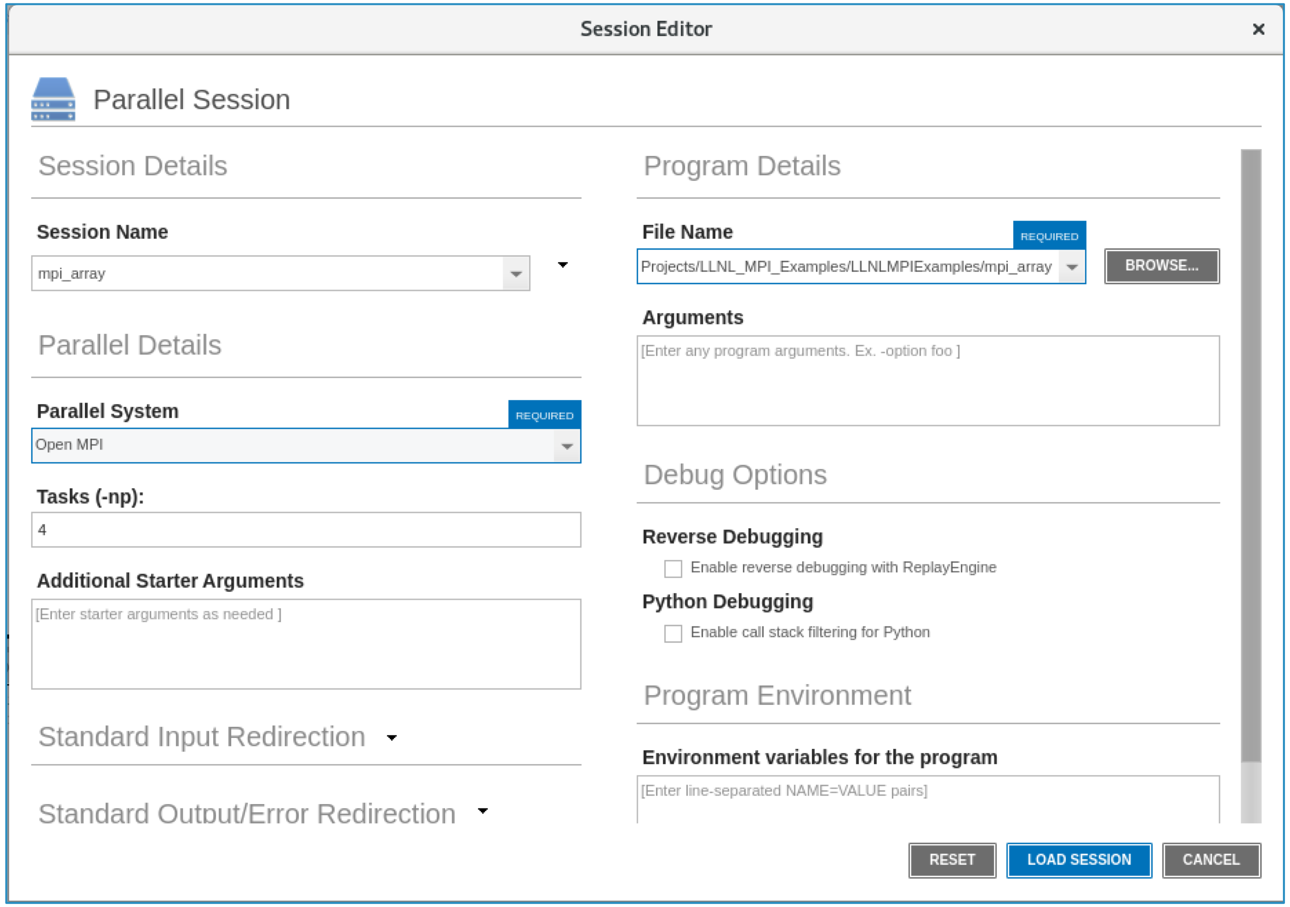
Debugging Parallel Applications

Multi-Thread and Multi-Process Debugging

- TotalView provides the power to
  - Simultaneously debug many threads and processes in a single debugging session
  - Supports MPI, fork/exec, OpenMP, pthreads, std::thread, et al
  - Help locate deadlocks and race conditions
  - Understand complex applications utilizing threads
- By
  - Providing control of entire groups of processes, individual processes or even down to individual threads within a process
  - Enabling thread level breakpoints and barrier controls
  - Showing aggregated thread and process state display

Starting a Parallel Program Session from the UI

- From New Parallel Session page select:
  - MPI preference
  - Number of tasks
  - Number of nodes
  - Starter arguments
- Click Start Session to save and launch



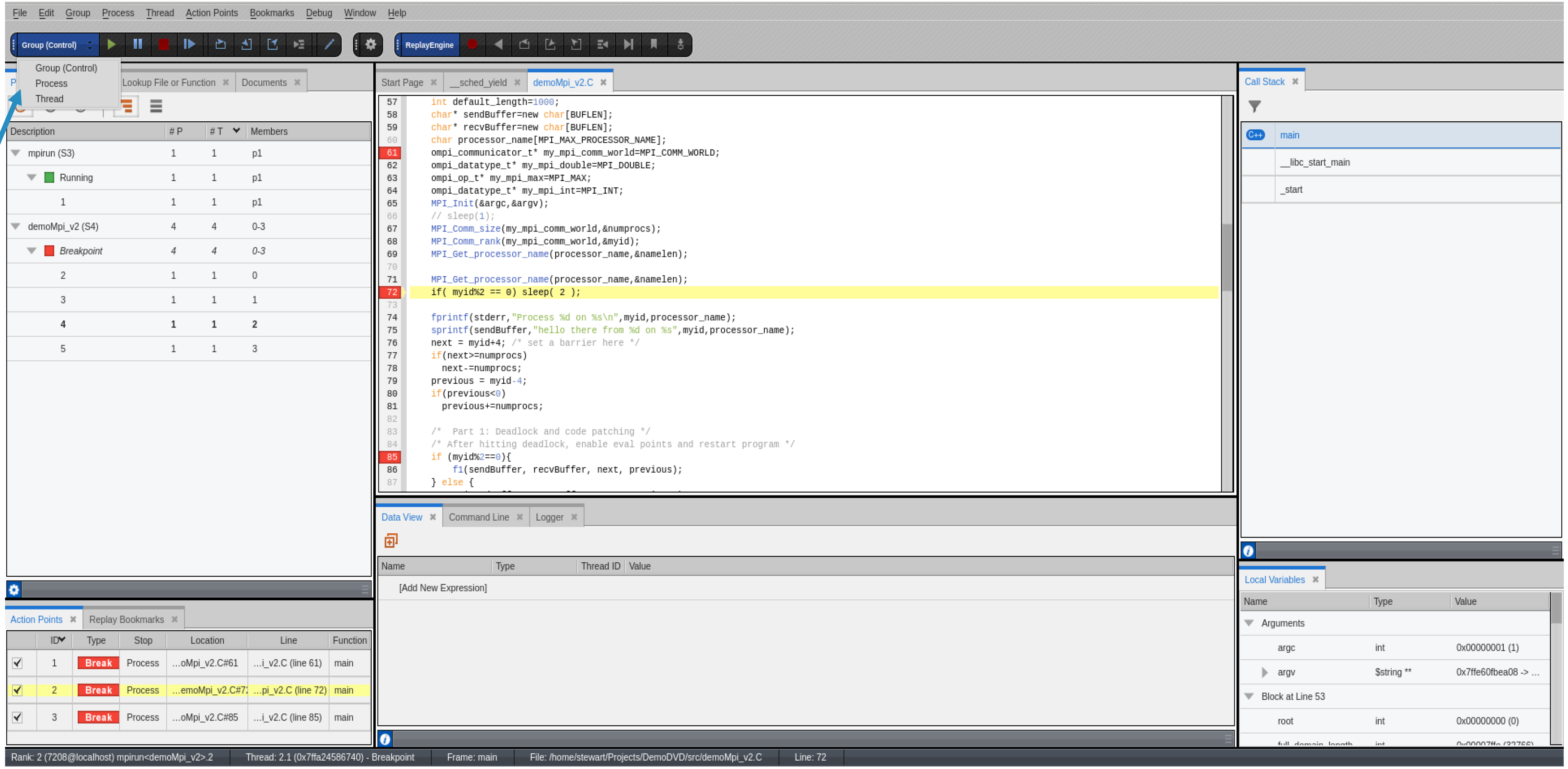
Starting a Parallel Program Session from the Command Line

MPI	Startup Command
IBM	totalview --args poe myprog -procs 4 -rmpool 0
QUADRICS Intel Linux under SLURM	totalview --args srun -n 16 -p pdebug myprog
MVAPICH Opteron Linux under SLURM	totalview --args srun -n 16 -p pdebug myprog
SGI	totalview --args mpirun myprog -np 16
Sun	totalview --args mprun myprog -np 16
MPICH	mpirun -np 16 -tv myprog
MPICH2 Intel MPI	totalview --args python ‘which mpiexec’ –tvsu -np 16 myprog

The order of arguments and executables differs between platforms

You can use totalview --args instead of totalview <starter> -a

Parallel Debugging Group, Process and Thread Control

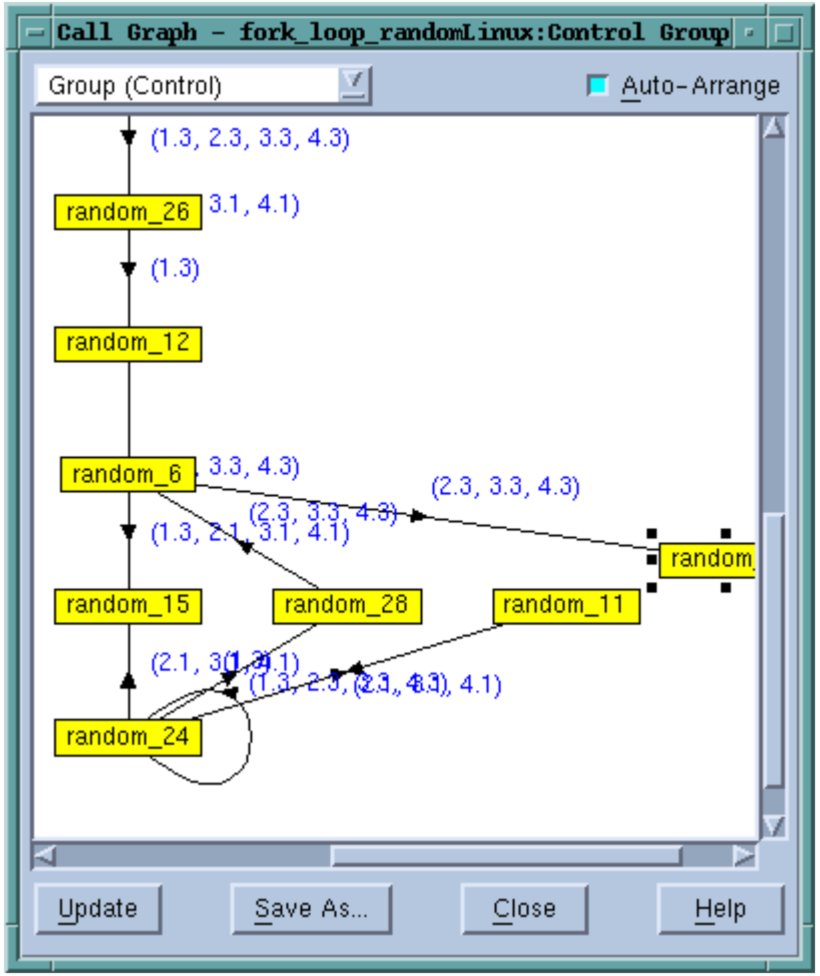


Select either
- Group
- Process
- Thread

Call Graph

Classic UI Only

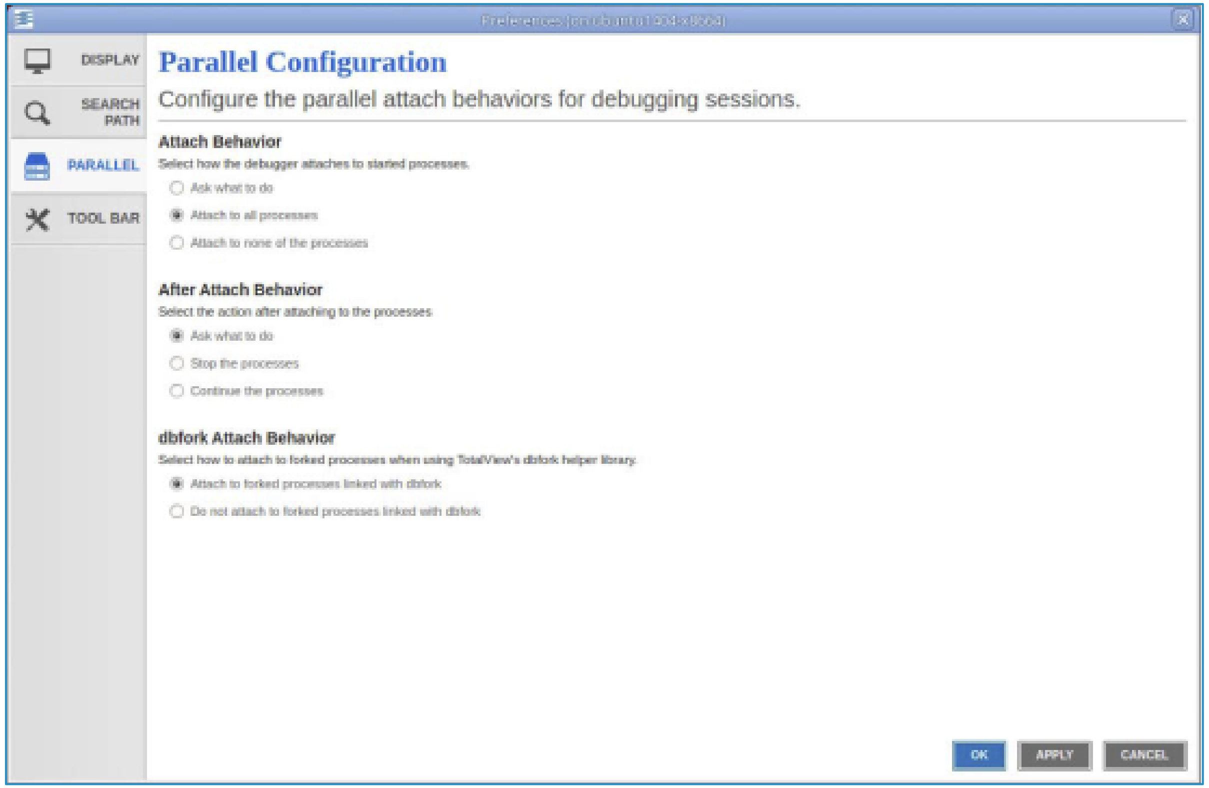
- Quick view of program state
  - Each call stack is a path
  - Functions are nodes
  - Calls are edges
    - Labeled with the MPI rank or thread ID
  - Construct process groups
  - Look for outliers
- Dive on a node in the call graph to create a Call Graph group.



Parallel Preferences

Attach Behavior controls if TotalView should attach to all of the processes, none or ask what to do

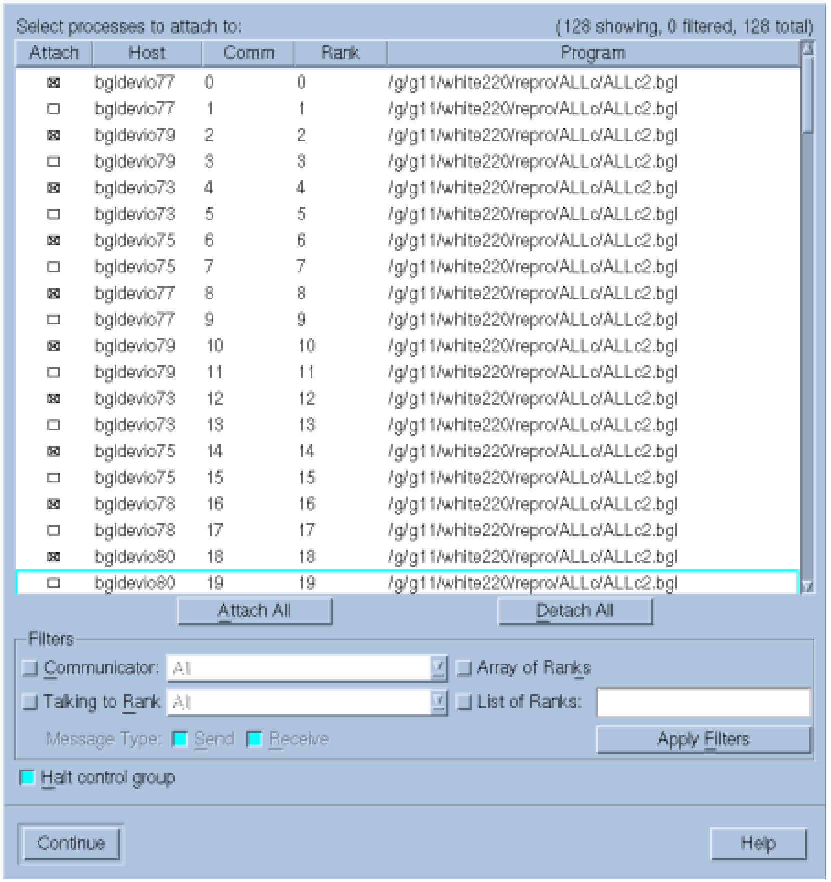
After Attach Behavior controls if parallel job stops, runs or if TotalView should ask what to do



Subset Attach - Control Which Processes TotalView Attaches To

- Debug a subset of the processes that make up the job
  - Sometimes the user does not need to control and see every process to understand the behavior or id the defect
- The subset can be changed at any time
  - Can narrow, expand or shift focus
- Uncouples interactive performance from job size
  - After the subset operation completes
  - Interactive performance depends on subset size
- Supports the use of lightweight tools
  - Such as LLNL's STAT

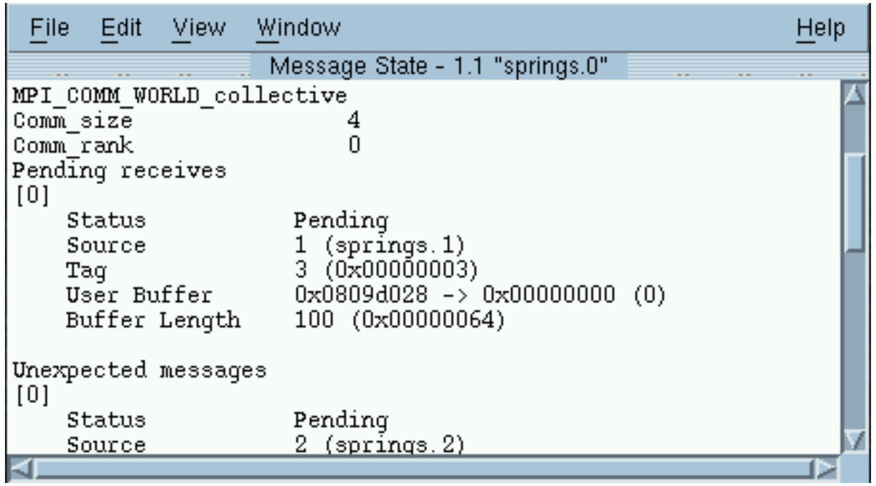
Classic UI Only



View MPI Message Queues

- Information visible whenever MPI rank processes are halted
- Provides information from the MPI layer
  - Unexpected messages
  - Pending Sends
  - Pending Receives
- Use this info to debug
  - Deadlock situations
  - Load balancing
- May need to be enabled in the MPI library
  - --enable-debug

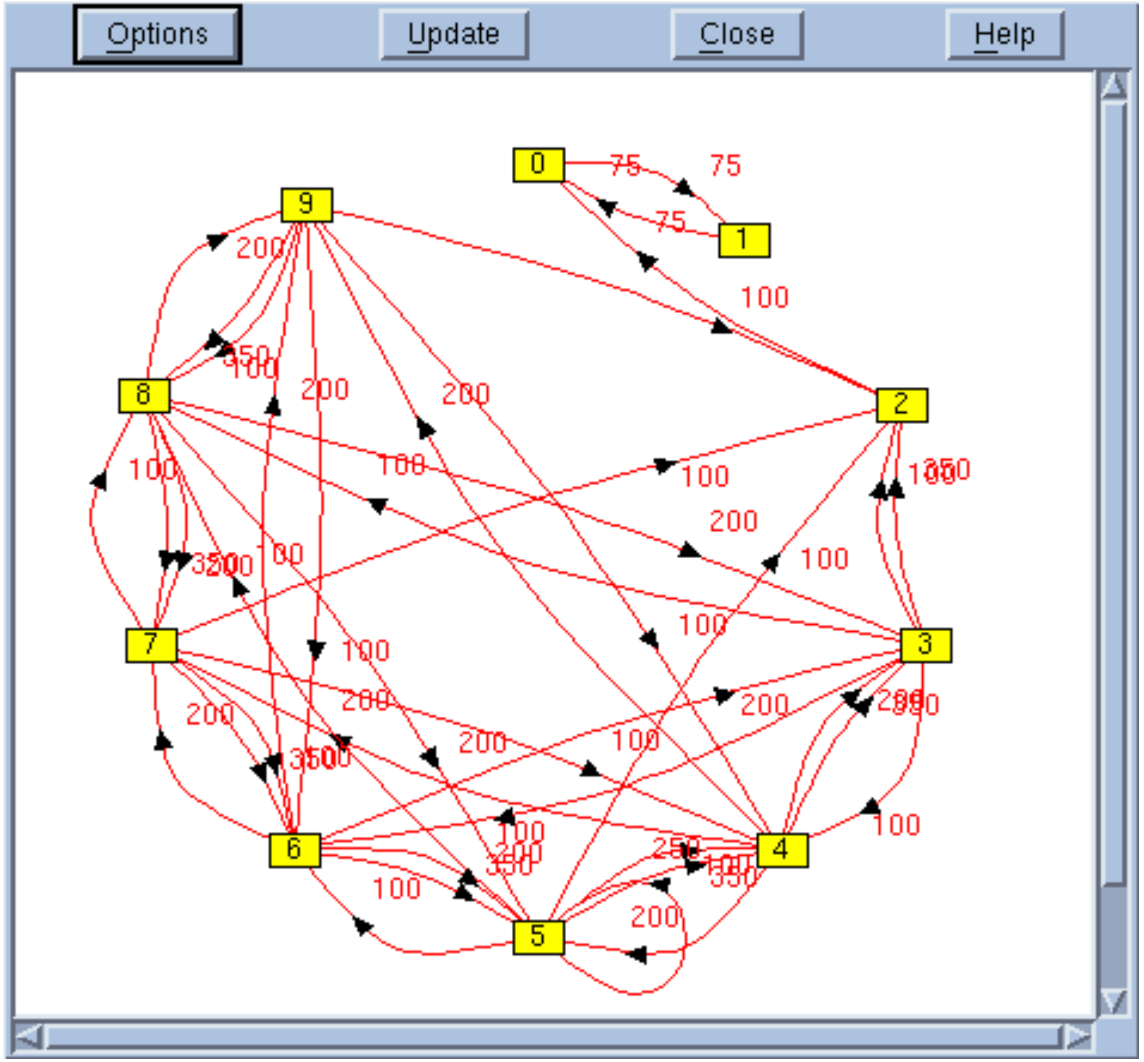
Classic UI Only



Message Queue Graph

Classic UI Only

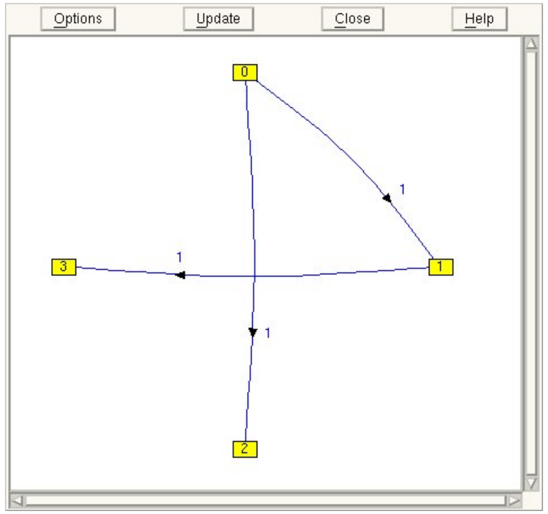
- Hangs & Deadlocks
- Pending Messages
    - Receives
    - Sends
    - Unexpected
- Inspect
    - Individual entries
- Patterns

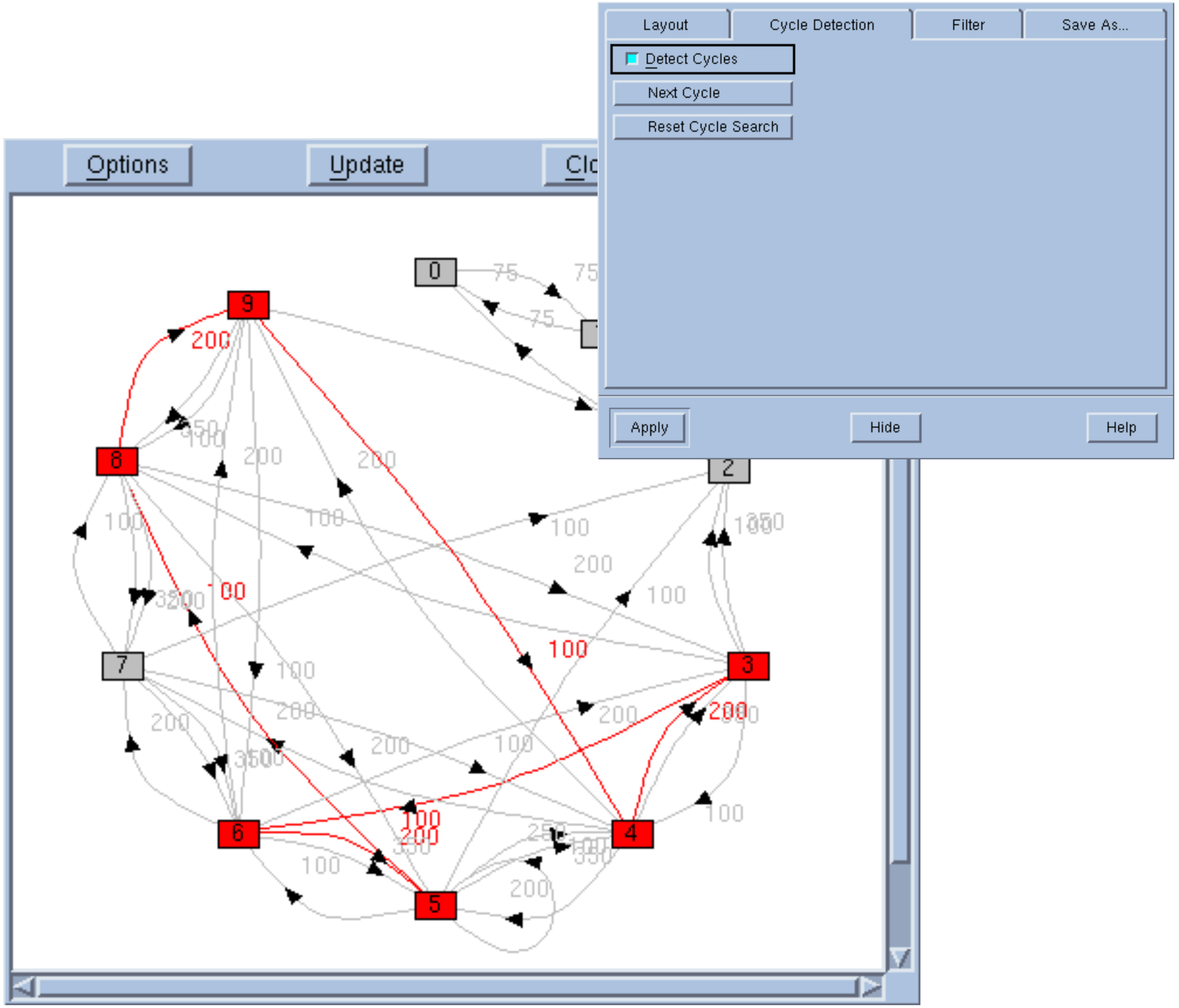


Find Deadlocks and Performance Sinks

Classic UI Only

- Filtering
  - Choose messages to track
  - Choose MPI Communicators
- Cycle detection





Multi-Thread Debugging Techniques

- Multiple ID's for threads
  - pthread library ID – Displayed by default in TotalView
  - OS Light Weight Process (LWP) ID
  - TotalView thread ID – ProcessID.ThreadID, e.g. 1.3
- Finding deadlocks due to mutex misuse
  - Utilize ReplayEngine/reverse debugging
  - Leverage watchpoints to find when mutex was acquired
  - Set the "Open process window at breakpoint" preference on the Action Points tab
  - To get LWP id, turn off TotalView user threads (-no_user_threads)
  - TotalView normally just displays the pthread ID

Multi-Thread Debugging Techniques

- Dealing with thread starvation
  - A tough problem to solve…
  - Utilize prior technique for watching when mutex’s are locked/unlocked
  - Leverage Evaluation Points and TotalView’s built-in Statements
    - $countthread expression
    - $holdthread
    - $stopthread
  - Halt the program during execution several times to see where execution is at in the Stack Trace

Multi-Process Debugging Techniques

- For high-scale debugging sessions, use command line launch of the parallel job instead of the Parallel Program Session in UI.
  - UI Parallel Program Session uses a flexible “bootstrap” parallel session mechanism for easy debug session setup but takes longer to launch.
- Enable reverse debugging on a per-process basis
  - Halt a specific process and enable reverse debugging on the fly
- Memory debugging can be enabled on one or more processes

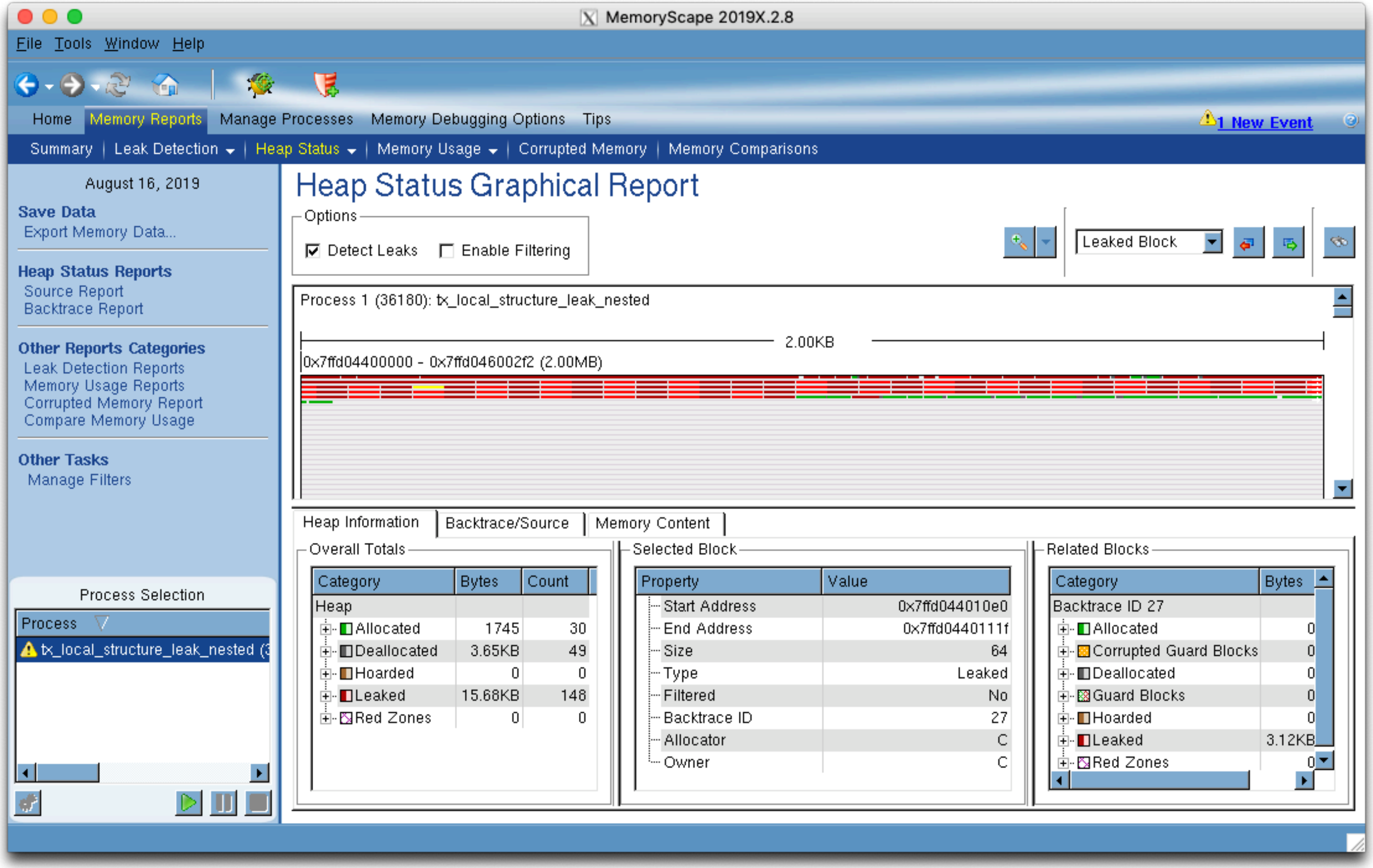
Demo

- TotalView MPI Demo (mpi_array_broken)

Memory Debugging with MemoryScape

MemoryScape – Simple to use, intuitive memory debugging

- What is MemoryScape?
  - Streamlined
  - Lightweight
  - Intuitive
  - Collaborative
  - Memory Debugging
- Features
  - Shows
    - Memory errors
    - Memory status
    - Memory leaks
    - Buffer overflows
  - MPI memory debugging
  - Remote memory debugging



What is a Memory Bug?

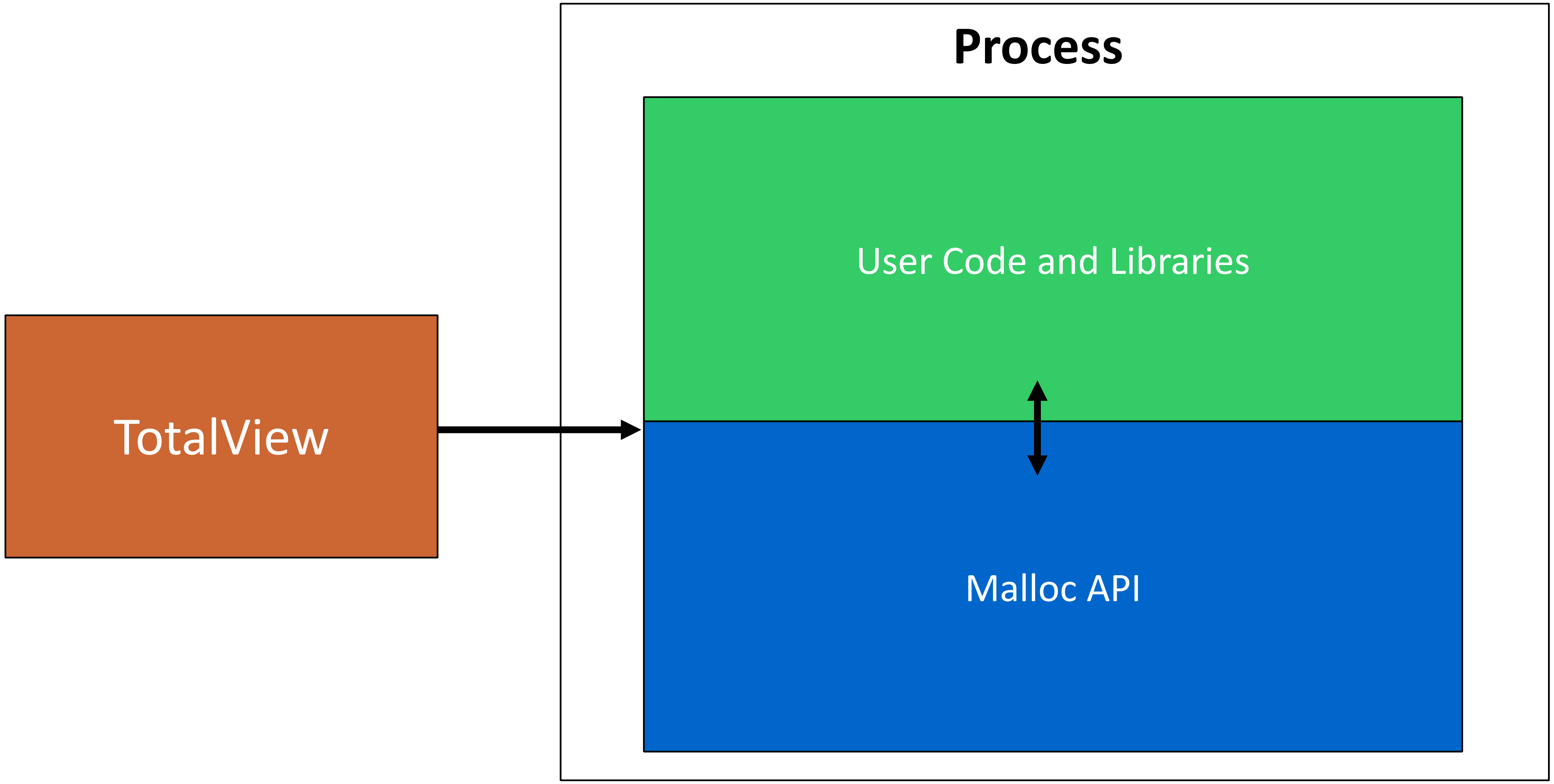
- A Memory Bug is a mistake in the management of heap memory
    - Leaking: Failure to free memory
    - Dangling references: Failure to clear pointers
    - Failure to check for error conditions
    - Memory Corruption
        - Writing to memory not allocated
        - Overrunning array bounds

Heap Memory

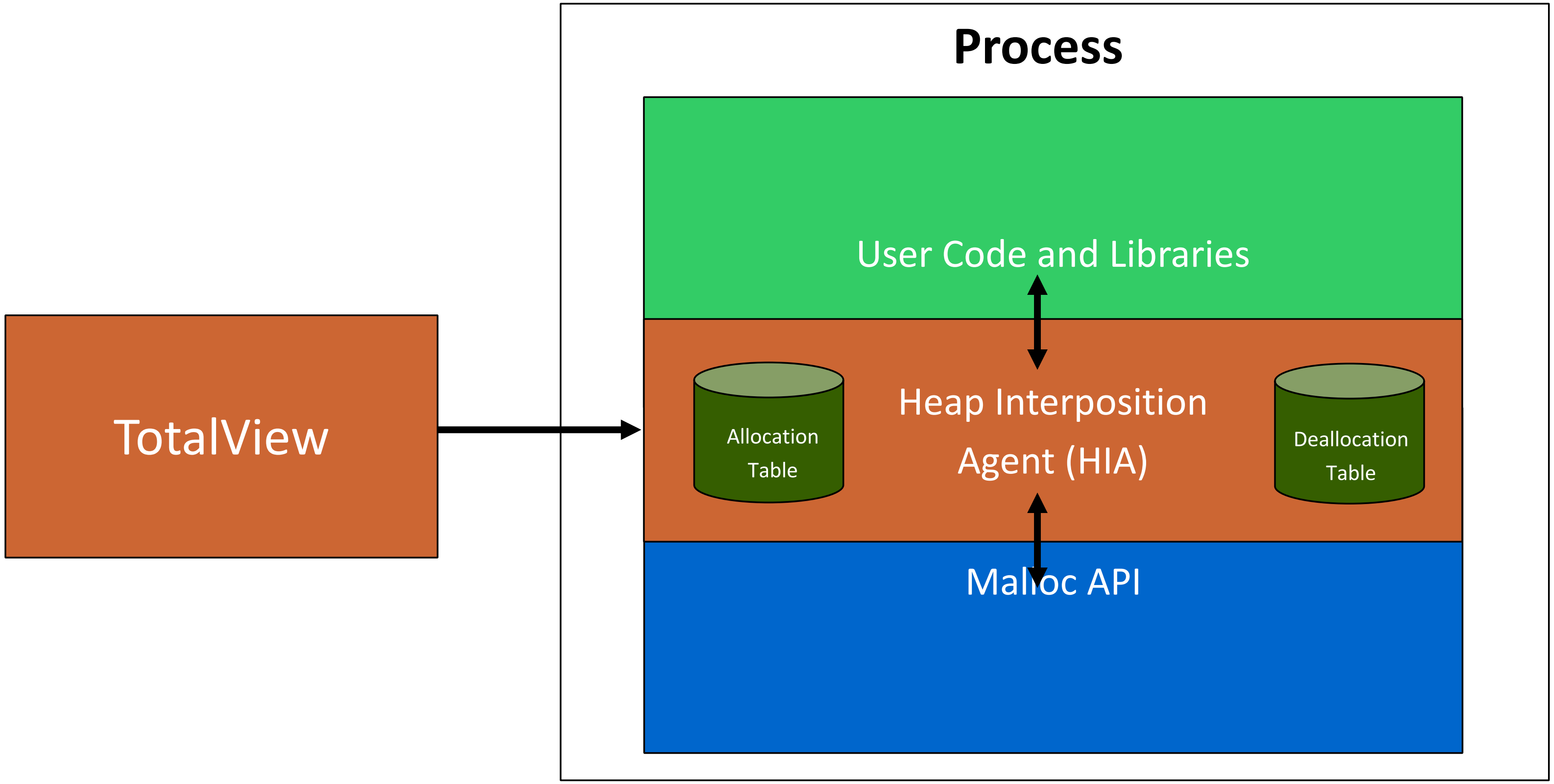
- Heap is managed by the program
  - C: Malloc() and free()
  - C++: New and Delete
  - Fortran90: Allocatable arrays
- Malloc usage is something like:

```
int * vp;
vp=malloc(sizeof(int)*number);
if (vp == 0){ /*malloc must have failed*/ }
/* use vp */
free(vp);
vp=0;
```

The Agent and Interposition



The Agent and Interposition



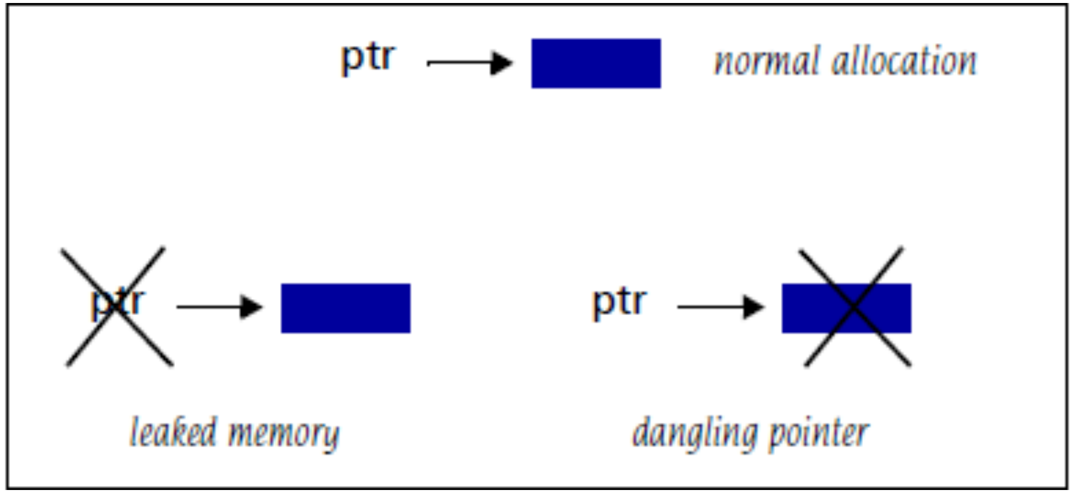
TotalView HIA Technology

- Advantages of TotalView HIA Technology
  - Use it with your existing builds
    - No Source Code or Binary Instrumentation
  - Programs run nearly full speed
    - Low performance overhead
  - Low memory overhead
    - Efficient memory usage

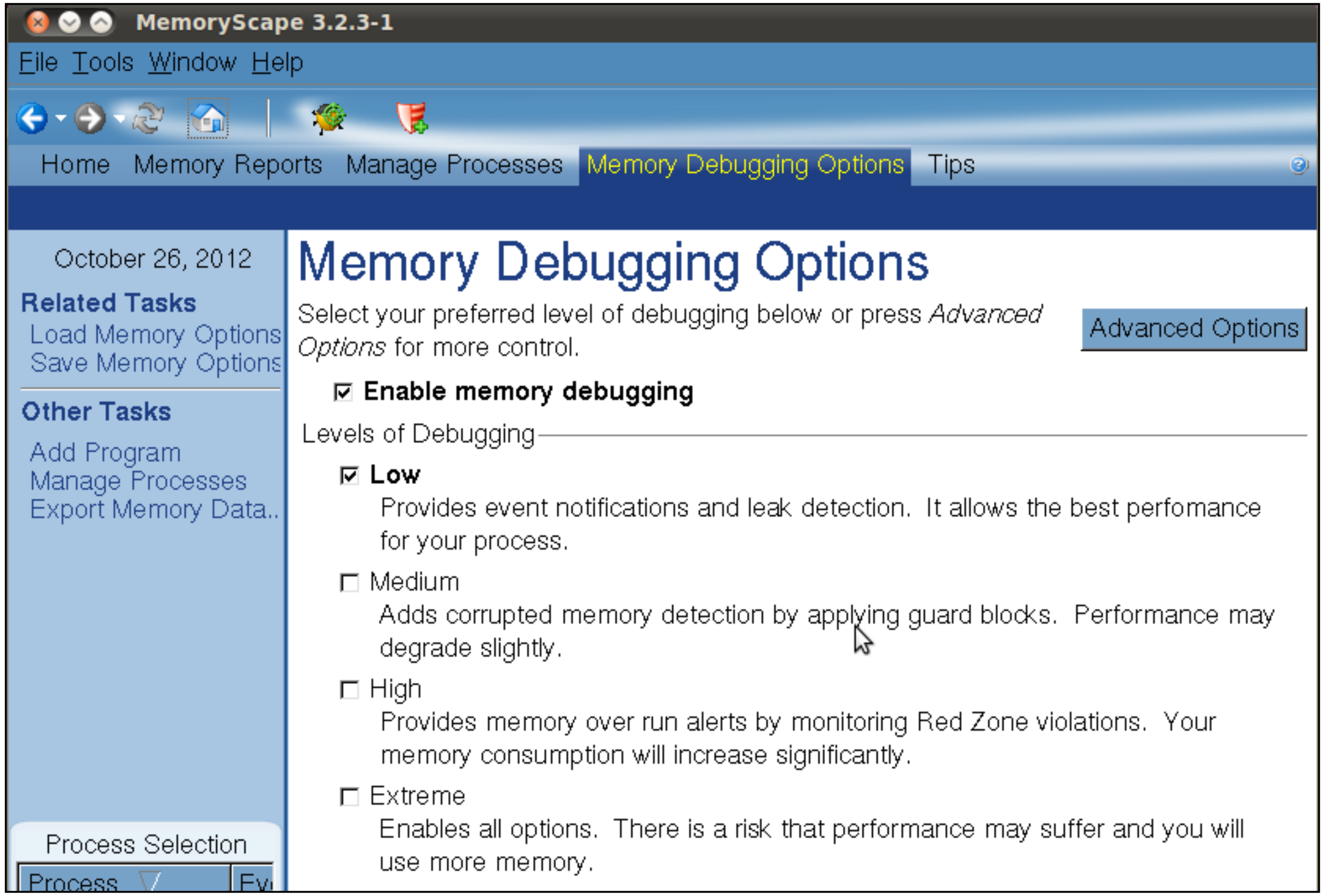
Memory Debugger Features

- Automatically detect allocation problems
- Memory Corruption Detection - Guard Blocks & Red Zones
- Leak detection
- Dangling pointer detection
- View the heap
- Memory Hoarding
- Memory Comparisons between processes

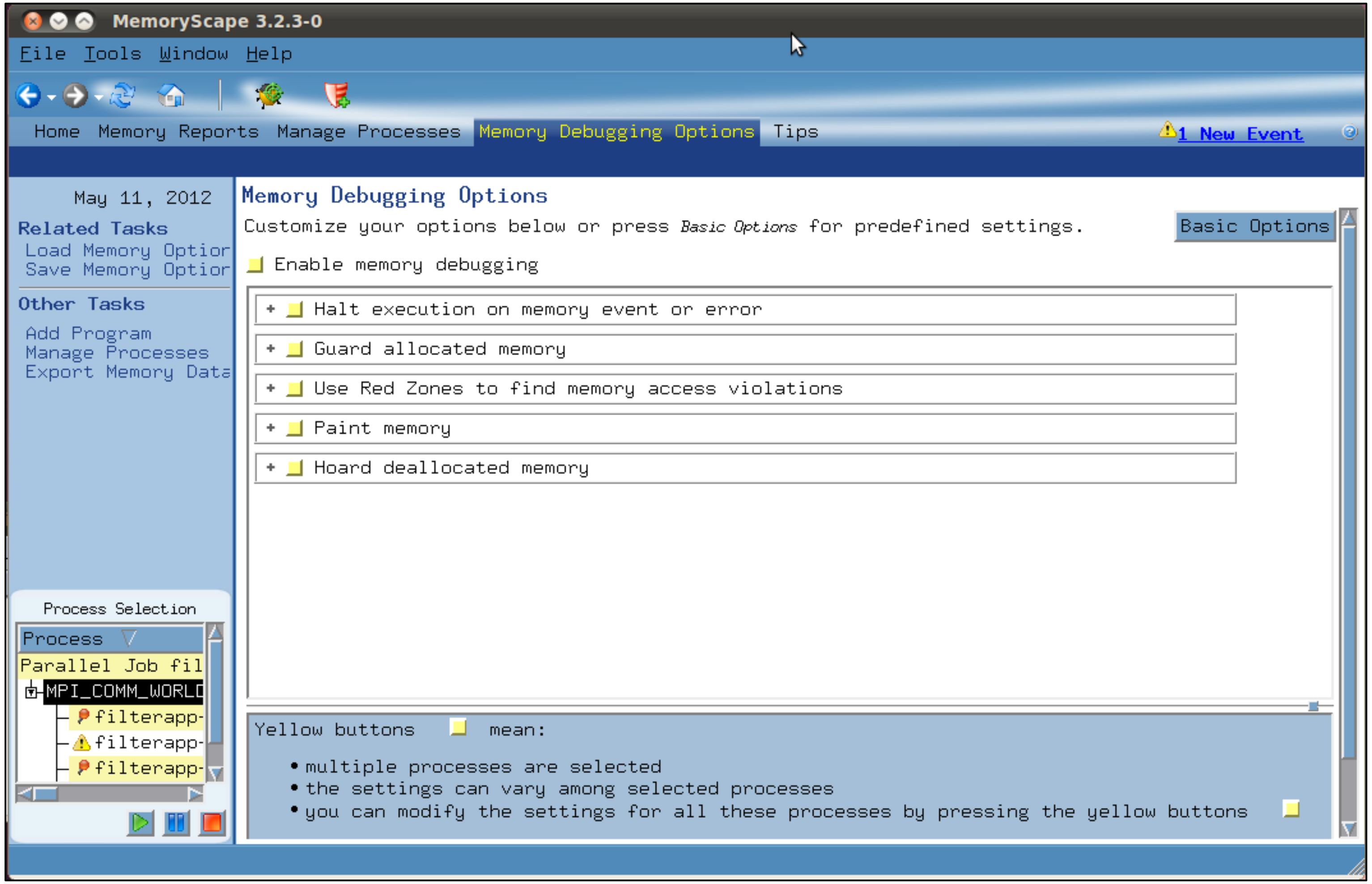
Leaks and Dangling Pointers



Memory Debugging Options



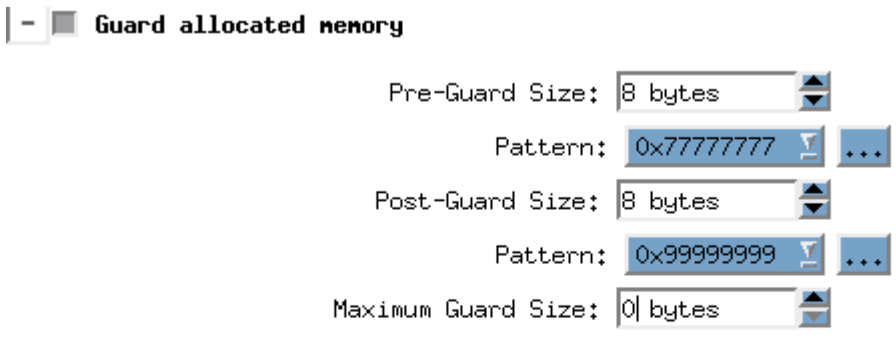
Advanced Memory Debugging Options



Guard Blocks

Guard allocated memory

When selected, the Memory Debugger writes guard blocks before and after a memory block that your program allocates



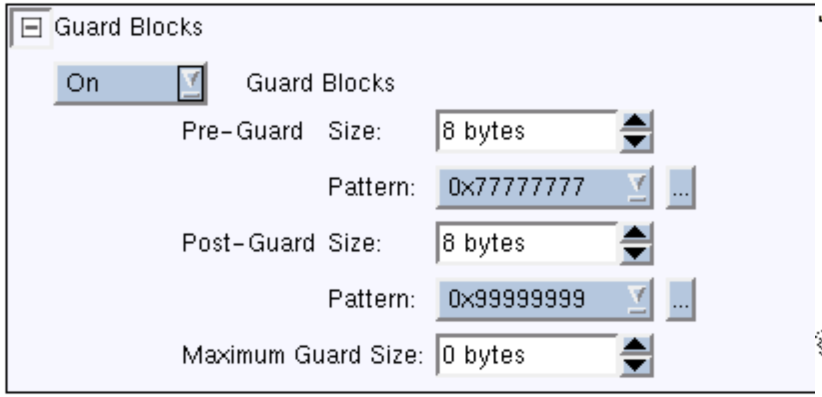
Pre-Guard and Post-Guard Size:

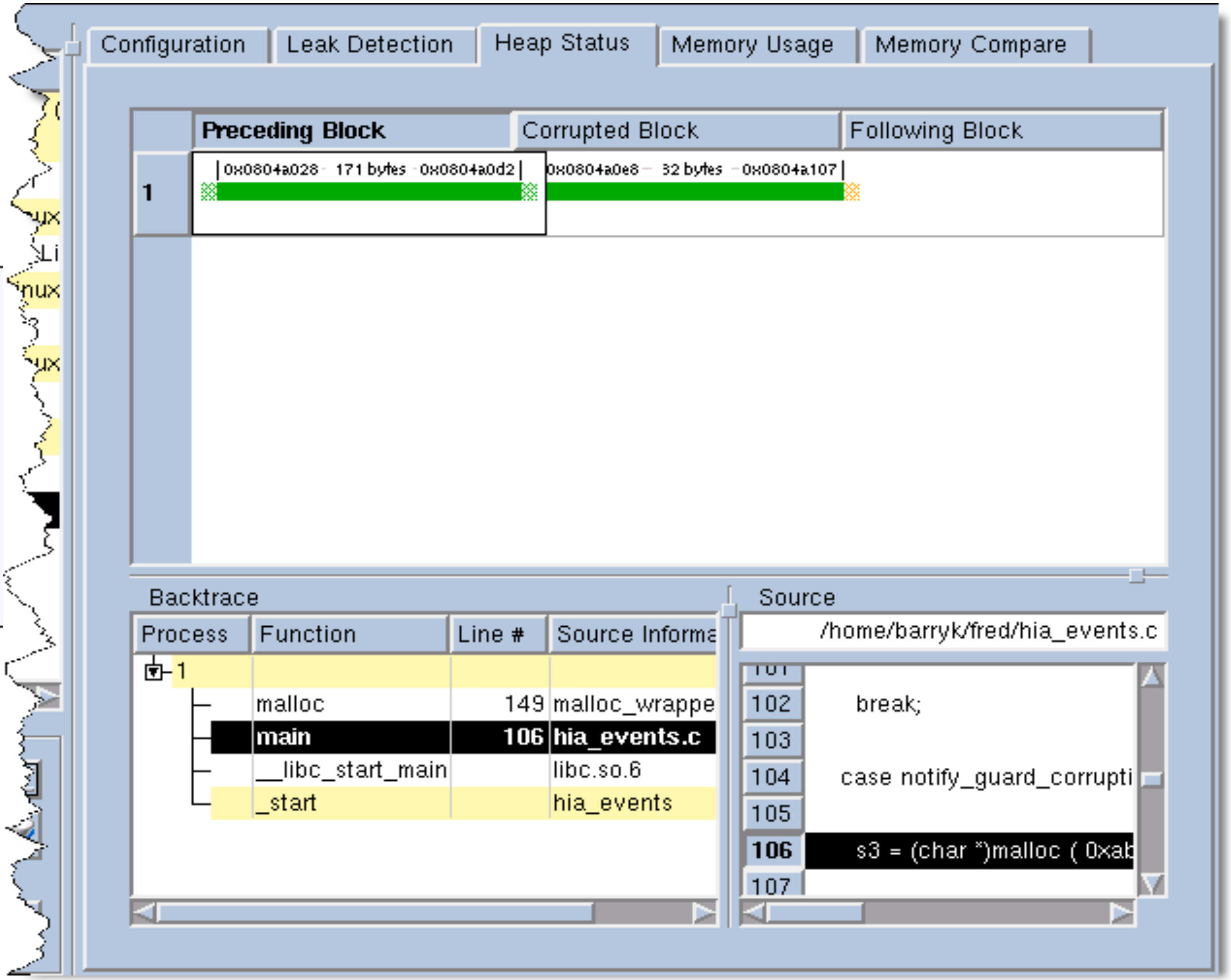
Sets the size in bytes of the block that the Memory Debugger places immediately before and after the memory block that your program allocates

Pattern:

Indicates the pattern that the Memory Debugger writes into guard blocks. The default values are 0x77777777 and 0x99999999

Guard Blocks





Red Zones

Red Zones : instant array bounds detection

- Red Zones provides:
  - Both read and write memory access violations.
  - Immediate detection of memory overruns.
  - Detection of access violations both before and after the bounds of allocated memory.
  - Detection of deallocated memory accesses.
- Red Zones events
  - MemoryScape will stop your programs execution and raise an event alerting you to the illegal access. You will be able to see exactly where your code over stepped the bounds.

Red Zones

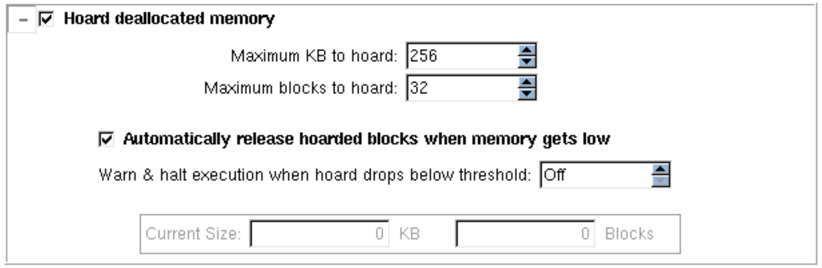
Red Zones instant array bounds detection for Linux

- Red Zones allocation size range controls
  - The optional use of Red zones will increase the memory consumption of your program.
  - Controls are provided to allow the full management of Red Zone usage. These controls allow:
    - Restriction of red zones to allocations in several user defined size ranges
    - Easily turning red zones on and off at any time during your programs execution.

Memory Painting

- Useful to track down when you read uninitialized or undefined memory
    - Before it has been initialized
    - After it has been freed
- Memory Painting allows you to inject known values into memory on memory allocation or on memory free
    - Good values don’t correspond to any valid address
    - Have a distinctive look
        - When cast to different types

Memory Hoarding

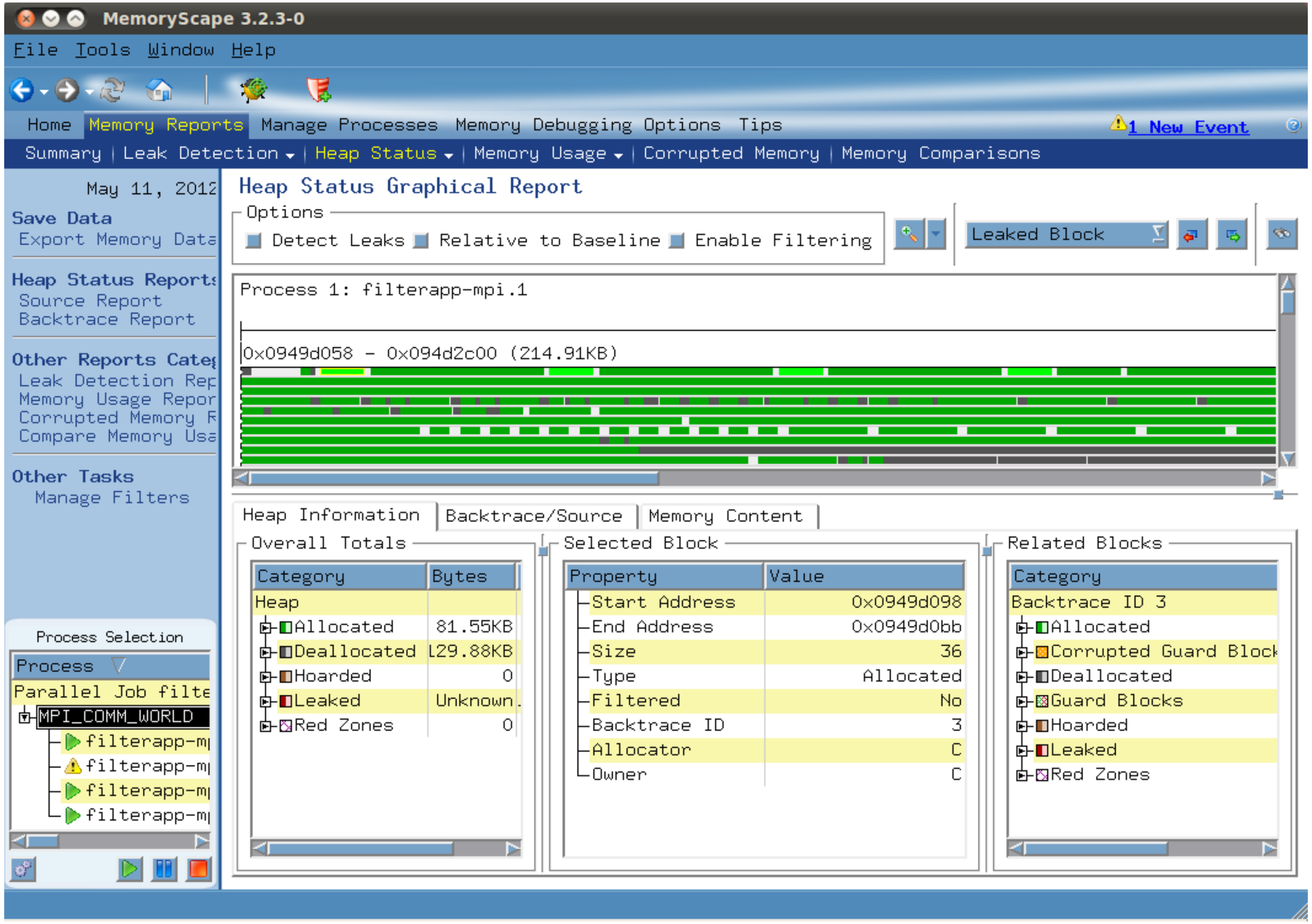


- Memory Hoarding
  - Stops the memory manager from reusing memory blocks
  - Can detect certain memory errors

- Hoard Low Memory Controls
  - Automatically release hoarded memory when available memory gets low, allowing your program to run longer

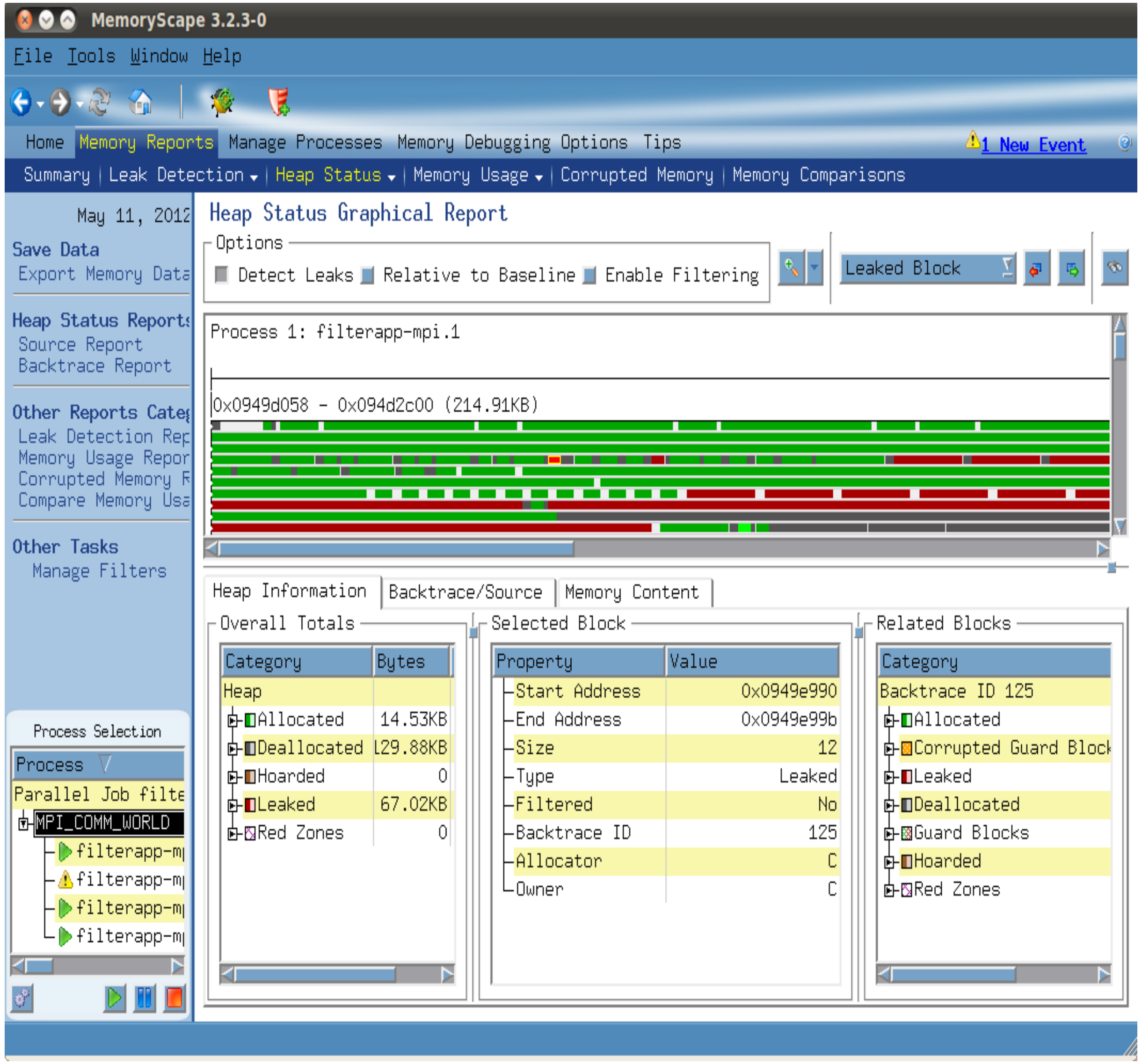
- Hoard Low Memory events
  - MemoryScape can stop execution as notification that the hoard droppped below a particular threshold. This provides an indication that the program is getting close to running out of memory.

Heap Graphical View



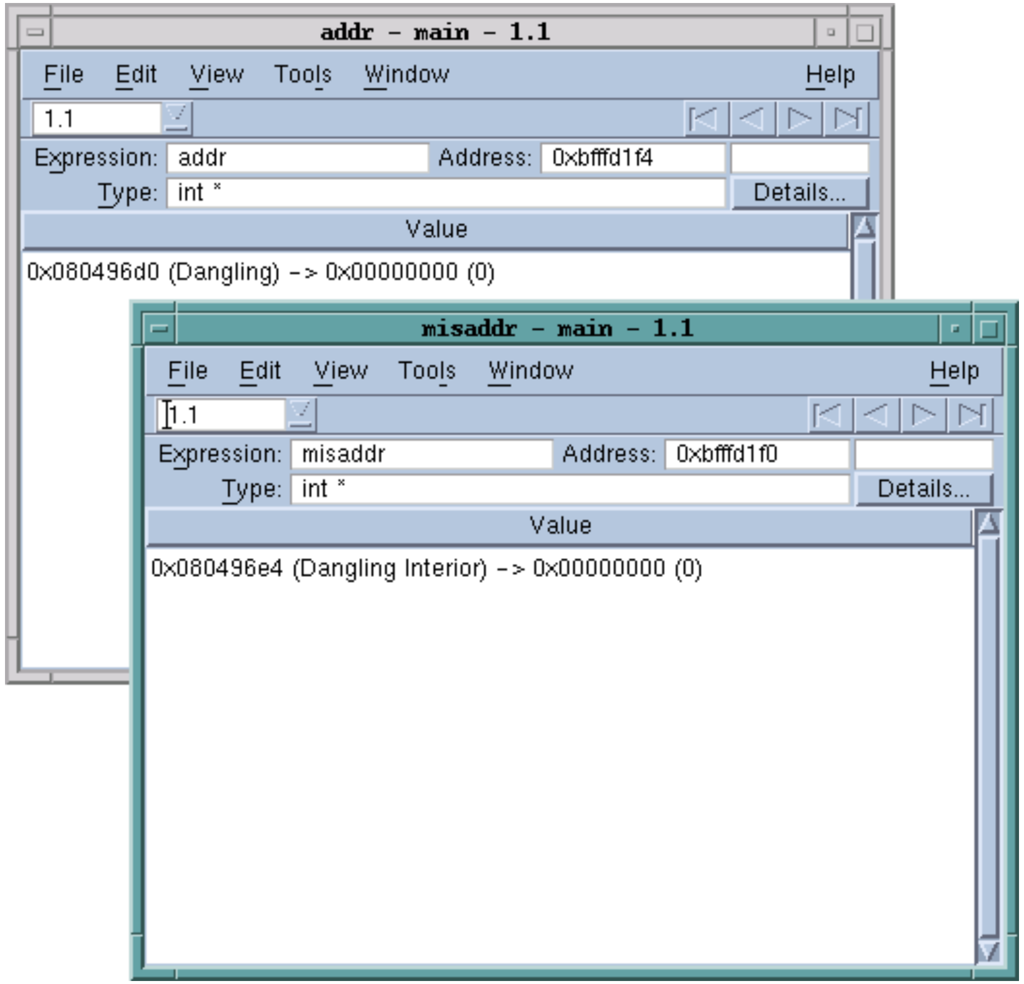
Leak Detection

- Leak Detection
  - Based on Conservative Garbage Collection
  - Can be performed at any point in runtime
    - Helps localize leaks in time
  - Multiple Reports
    - Backtrace Report
    - Source Code Structure
    - Graphically Memory Location



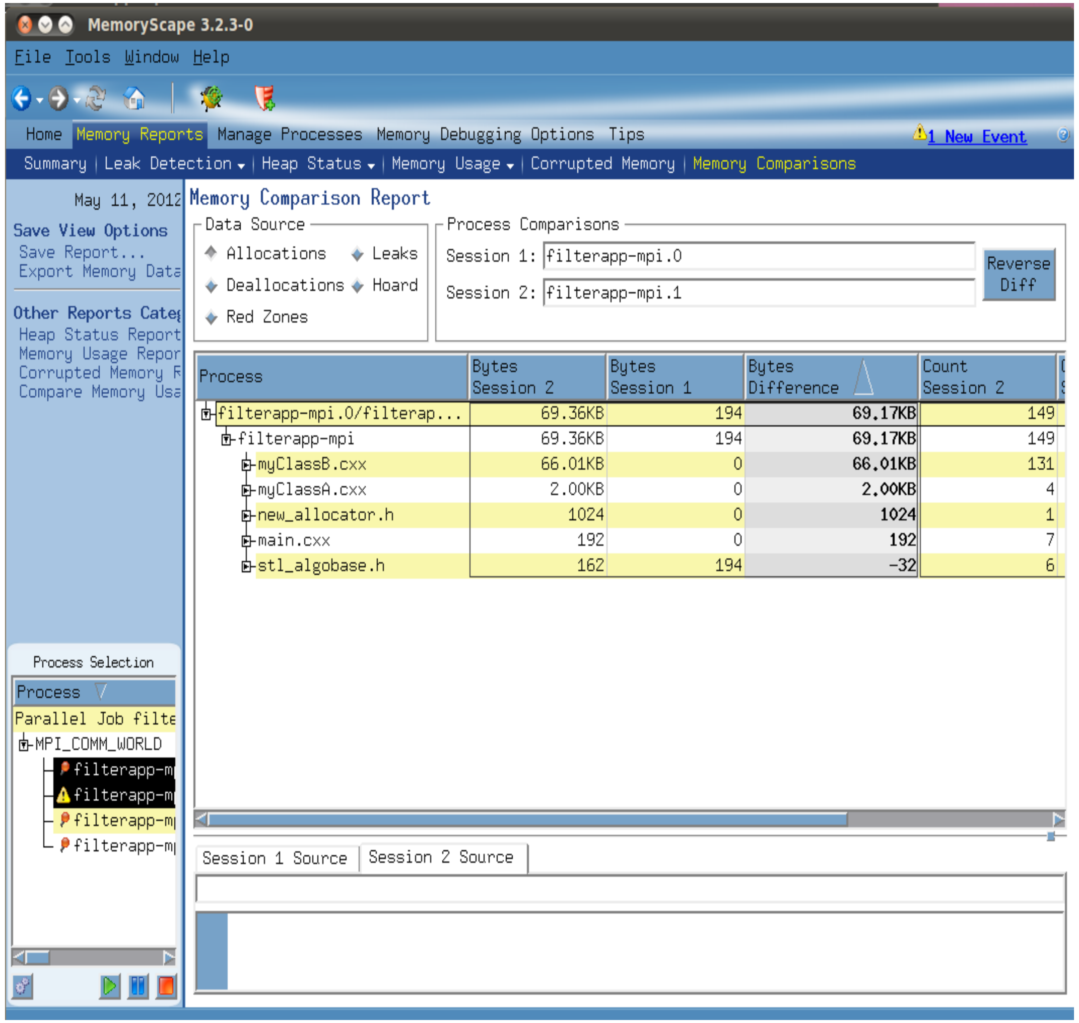
Dangling Pointer Detection

Classic UI Only

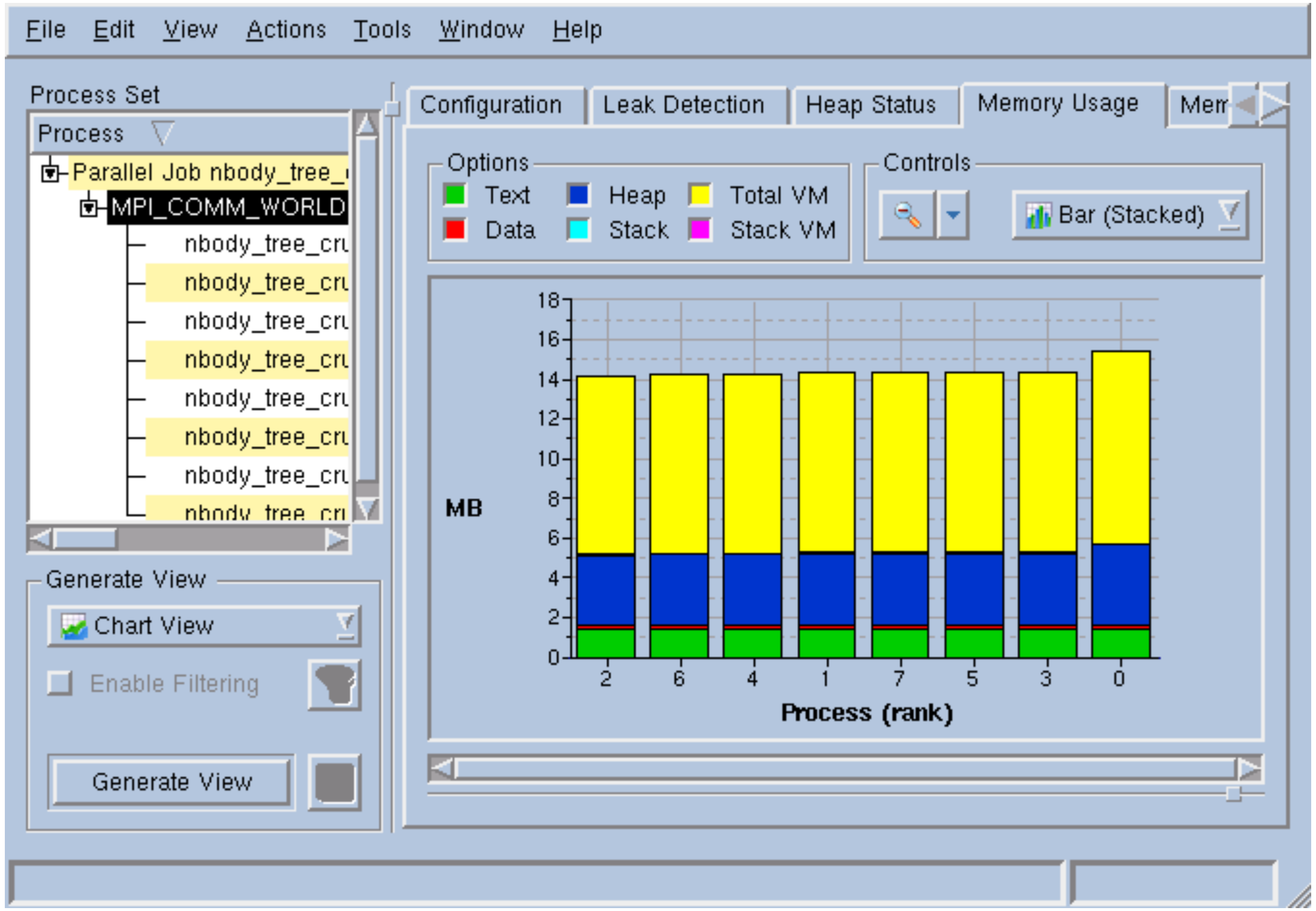


Memory Comparisons

- “Diff” live processes
    - Compare processes across cluster
- Compare with baseline
    - See changes between point A and point B
- Compare with saved session
    - Provides memory usage change from last run

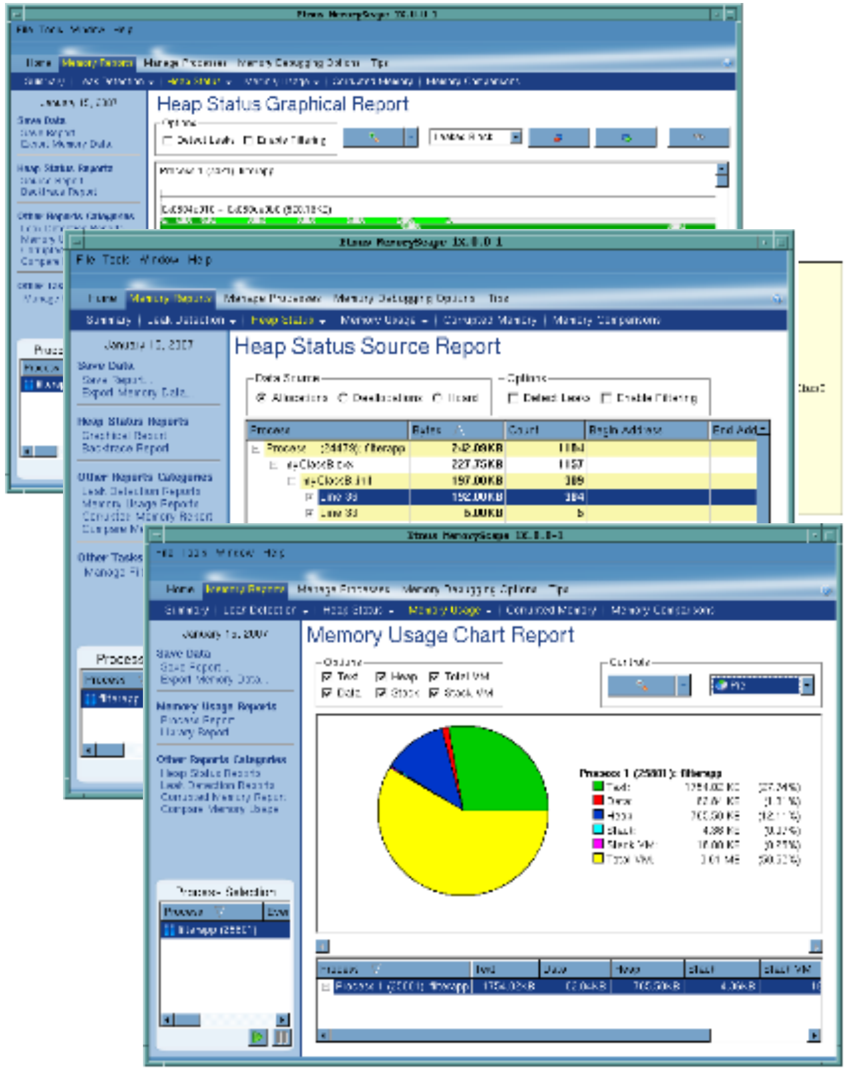


Memory Usage Statistics



Memory Reports

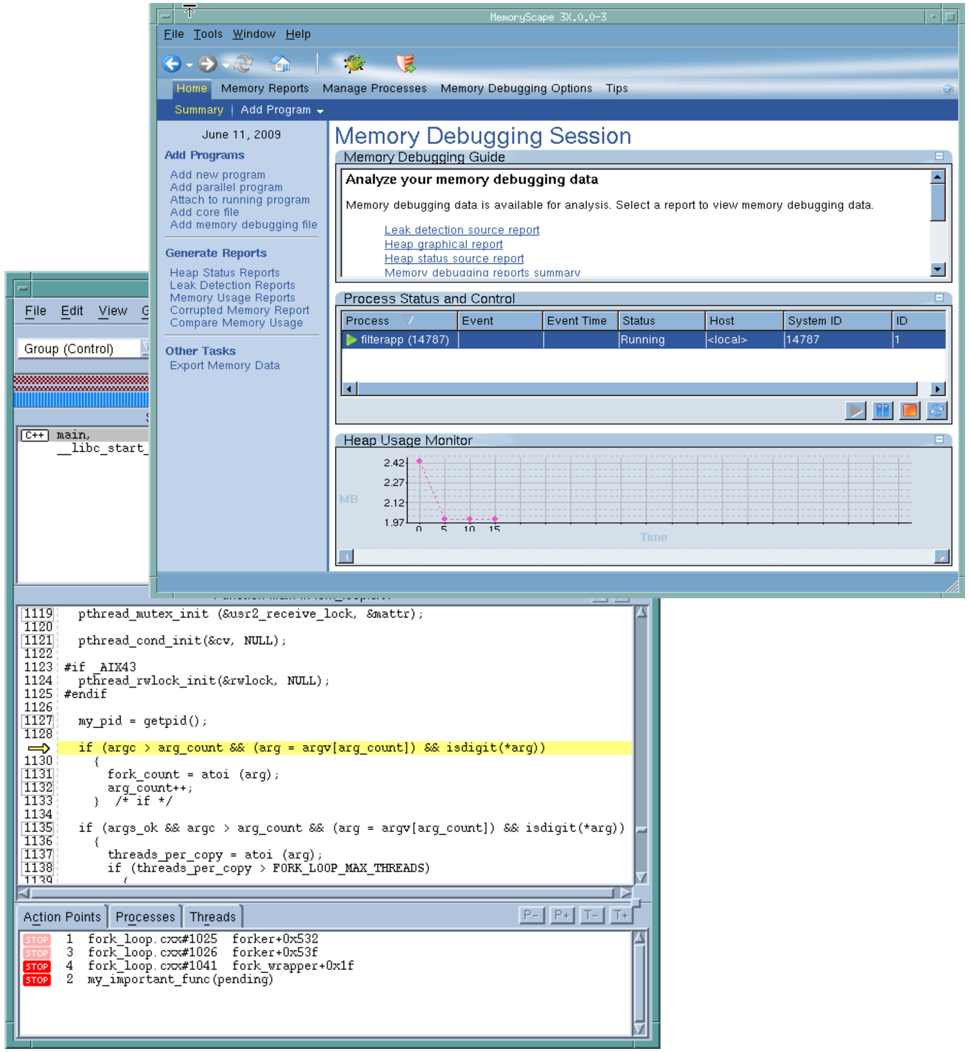
- Multiple Reports
  - Memory Statistics
  - Interactive Graphical Display
  - Source Code Display
  - Backtrace Display
- Allow the user to
  - Monitor Program Memory Usage
  - Discover Allocation Layout
  - Look for Inefficient Allocation
  - Look for Memory Leaks



TotalView and MemoryScape

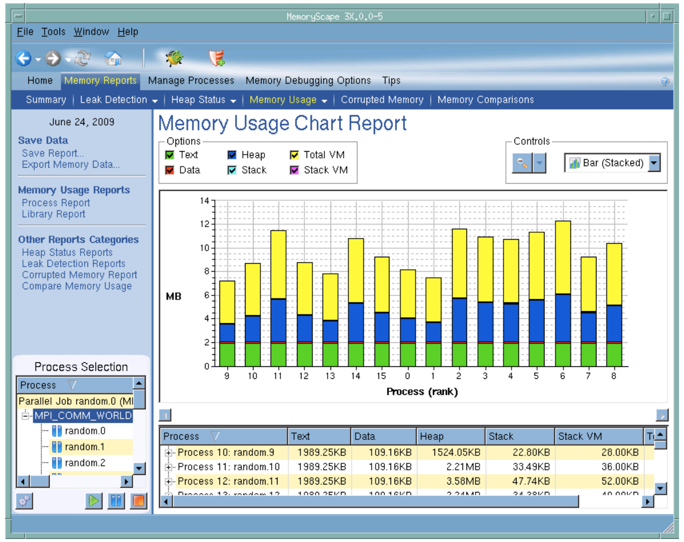
Classic UI Only

- You can use TotalView and MemoryScape together on an application.
- More precise control
  - Breakpoints
  - Stepping
- Visibility into
  - Memory behavior
  - Variable contents
- Advanced features
  - Heap baseline
  - Dangling pointer annotation
  - Memory painting



Strategies for Memory Debugging in Parallel

- Run the application and see if memory events are detected
- View memory usage across the MPI job
    - Compare memory footprint of the processes
        - Are there any outliers? Are they expected?
- Gather heap information in all processes of the MPI job
    - Select and examine individually
        - Look at the allocation pattern. Does it make sense?
        - Look for leaks
    - Compare with the 'diff' mechanism
        - Are there any major differences? Are they expected?



Demo

- MemoryScape Demo

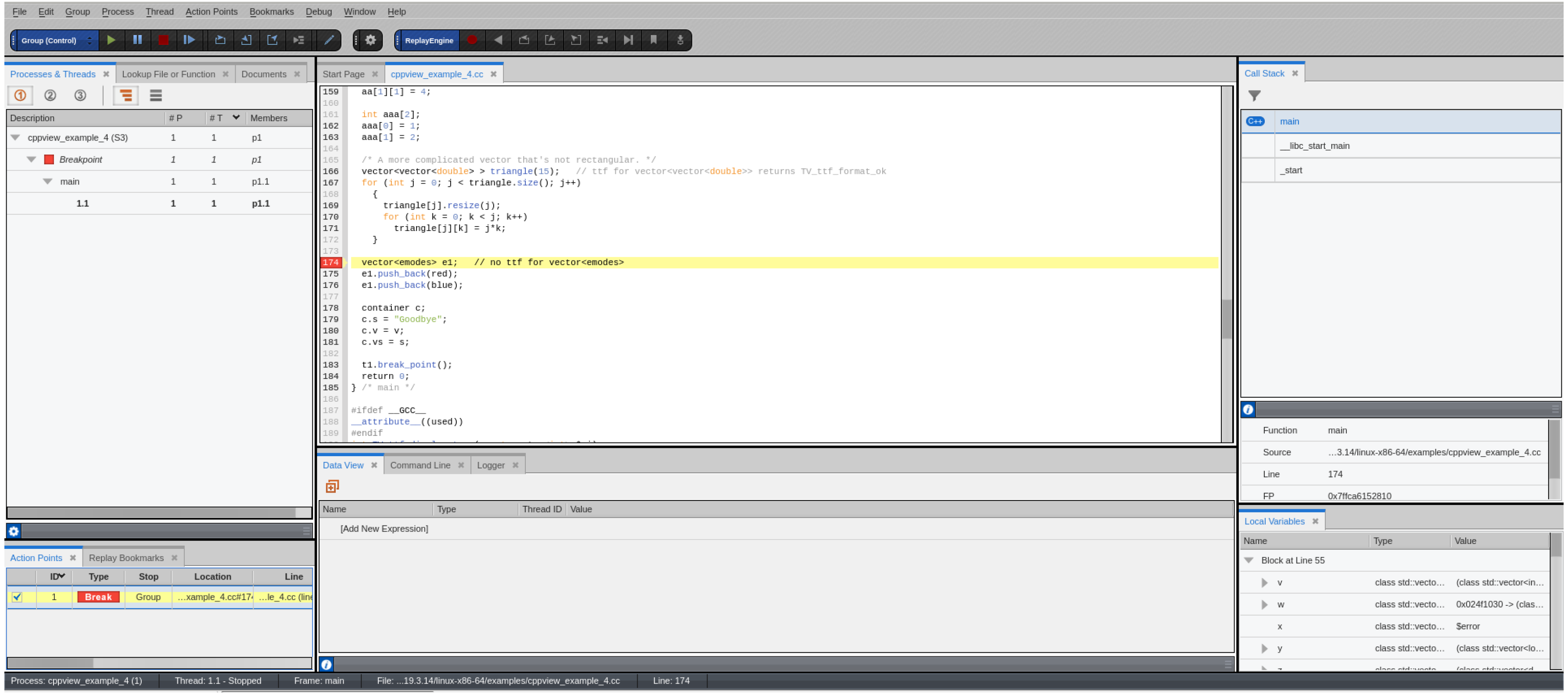
Transformations

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



C++ View API

```
#include "tv_data_display.h

int TV_ttf_display_type ( const T * );

int TV_ttf_add_row (
                    const char *field_name,
                    const char *type_name,
                    const char *address );
```

C++ View Example

```
class A {
        int i;
        char *s;
};

class B {
        A a;
        double d;
};

int TV_ttf_display_type ( const A *a )
{
        (void) TV_ttf_add_row ( "i", TV_ttf_type_int, &(a->i) );
        (void) TV_ttf_add_row ( "s", TV_ttf_type_ascii_string, a->s );
}

int TV_ttf_display_type ( const B *b )
{
        (void) TV_ttf_add_row ( "a", "A", &(b->a) );
        (void) TV_ttf_add_row ( "d", "double", &(b->d) );
}
```

Type Transformation Facility (TTF)

TTF is a TotalView subsystem that

- Allows you to transform the way information appears
- Doesn't require changes to your code
- TTF transforms can be stored in a .tvd file for referencing during a debugging session or at TotalView startup

QT Qstring class transform

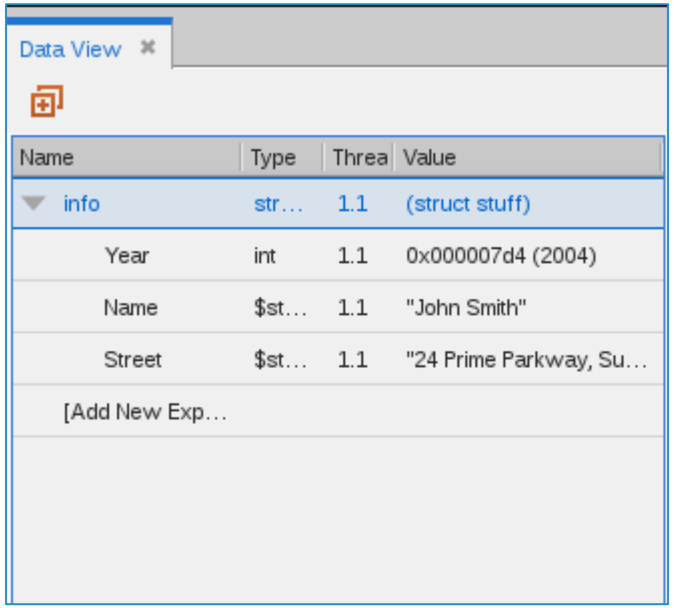
```
::TV::TTF::RTF::build_struct_transform {
   name {^class QString$}
   members {
     { ascii { $wstring_u16 cast {* {d -> data} } } }
   }
}
```

Type Transformation Facility (TTF)

```
#include <stdio.h>
int main () {
        struct stuff {
            int month;
            int day;
            int year;
            char * pName;
            char * pStreet;
            char CityState[30];
        };
}
```

Type Transformation Facility (TTF)

```
::TV::TTF::RTF::build_struct_transform {
        name {^struct stuff$}
        members {
                { year { year } }
                { Name { * pName } }
                { Street { * pStreet } }
        }
}
```



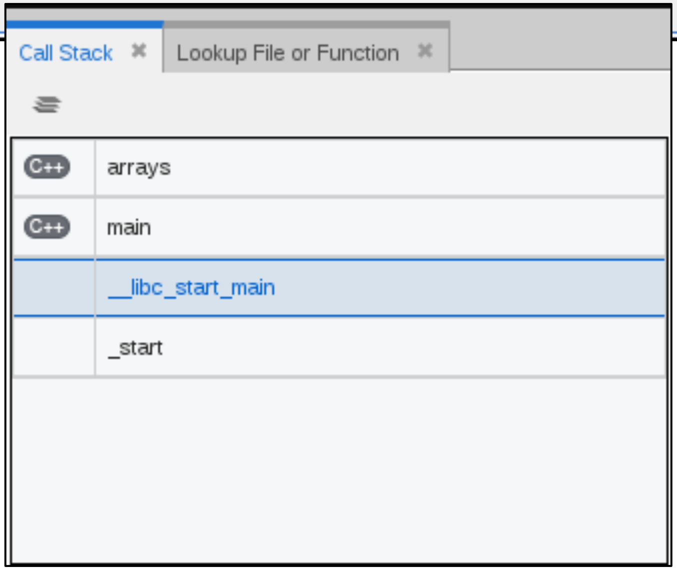
Stack Transformation Facility (STF)

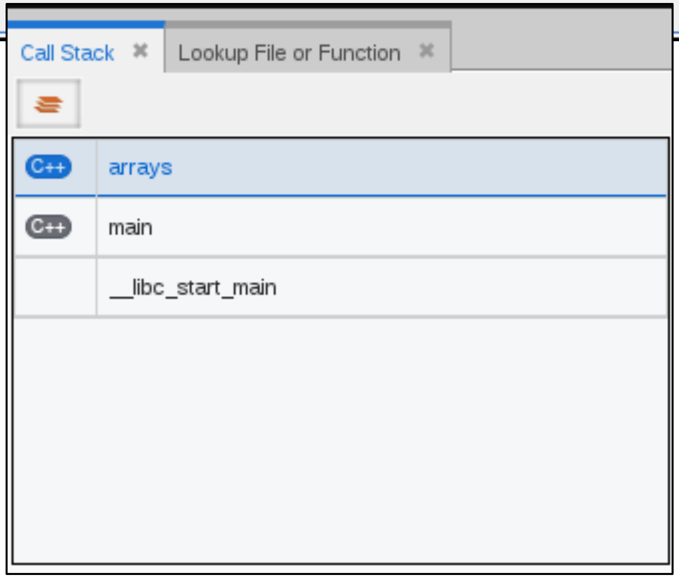
- Hides stack frames
- Transforms stack frames
- Backbone for:
  - Python support
  - OpenMP support
- Useful for any glue code you want to hide
  - Language differences
  - Wrapper code

```
d1.<> dstacktransform list
Transformation Status: Enabled

Rules
 ID Transform      Operation  Filter
  1 RW_Python      modify     image('python[2-9]\.[0-9]+-dbg'),function('PyEval_EvalFrameEx')
  2 RW_Python      remove     image('python[2-9]\.[0-9]+-dbg')

Transforms
 Name            Implementation
 RW_Python       <built-in>
```

Stack Transformation Facility (STF)

```
Thread 1.1 has appeared
Created process 1 (11617), named "combined"
Thread 1.1 has appeared
Thread 1.1 has exited
Thread 1.1 hit breakpoint 8 at line 514 in "arrays(void)"
d1.<> dstacktransform enable
enabled
d1.<> dwhere
>  0 arrays           PC=0x00402c05, FP=0x7ffdffd5d440 [/home/dstewart/Projects/Totalview/DemoDvD/src/combined.cxx#514]
   1 main             PC=0x004017db, FP=0x7ffdffd5d4a0 [/home/dstewart/Projects/Totalview/DemoDvD/src/combined.cxx#33]
   2 __libc_start_main PC=0x7f42b17e2b13, FP=0x7ffdffd5d560 [/lib64/libc.so.6]
   3 _start           PC=0x004016d4, FP=0x7ffdffd5d568 [/home/dstewart/Projects/Totalview/DemoDvD/programs/combined]

d1.<> dstacktransform add -transform MY_TRANSFORMS -filter "function('^_start')" -operation remove
Rule 4 added.
4
d1.<> dwhere
>  0 arrays           PC=0x00402c05, FP=0x7ffdffd5d440 [/home/dstewart/Projects/Totalview/DemoDvD/src/combined.cxx#514]
   1 main             PC=0x004017db, FP=0x7ffdffd5d4a0 [/home/dstewart/Projects/Totalview/DemoDvD/src/combined.cxx#33]
   2 __libc_start_main PC=0x7f42b17e2b13, FP=0x7ffdffd5d560 [/lib64/libc.so.6]

d1.<> |
```





Demo

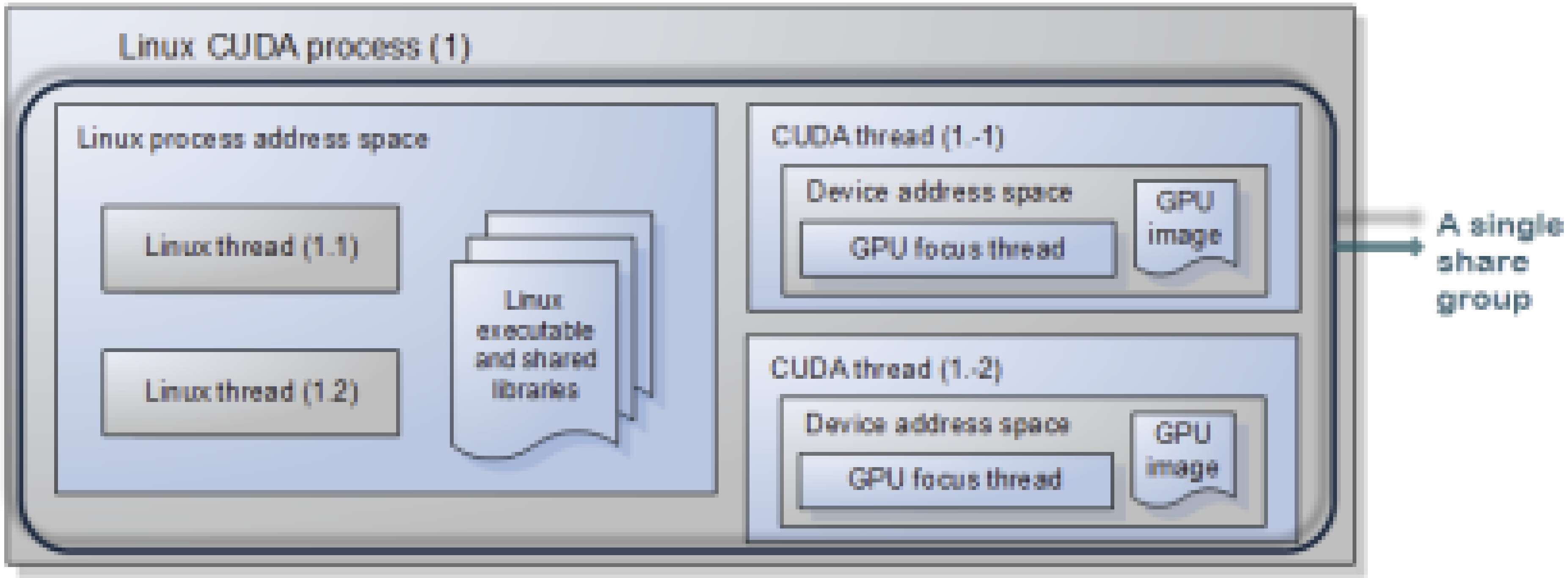
- TTF Demo (ttfdemo_customer example)

TotalView for CUDA

TotalView for the NVIDIA ® GPU Accelerator

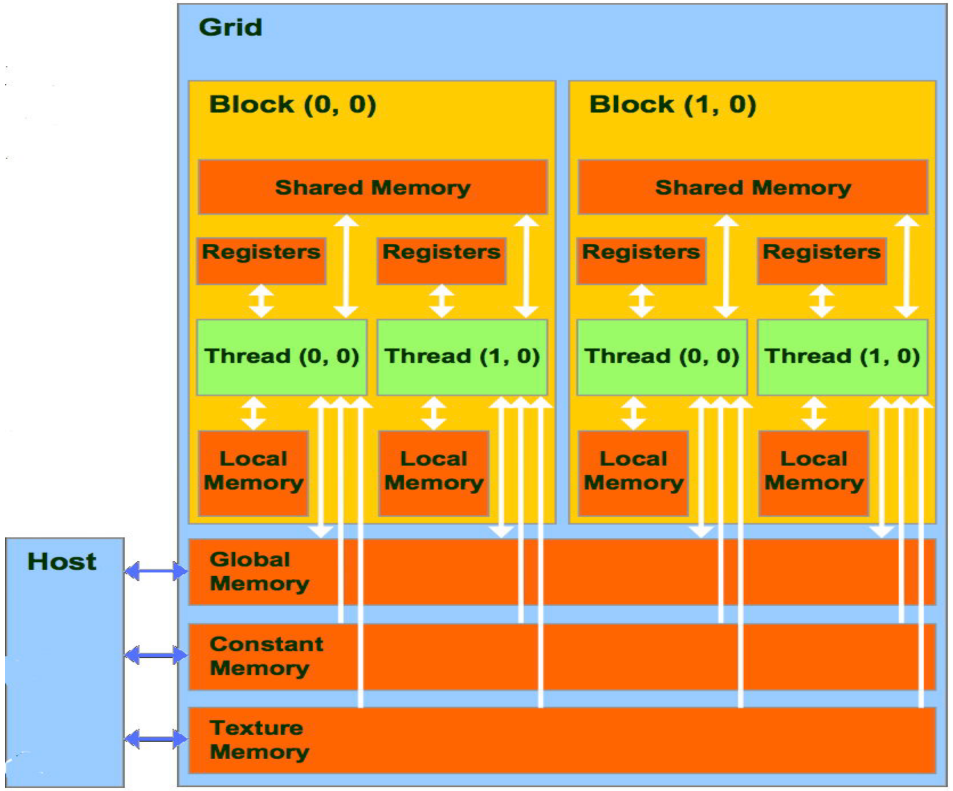
- NVIDIA Tesla, Fermi, Kepler, Pascal, Volta or Turing
- NVIDIA Ampere cards are in testing
- NVIDIA CUDA 9.2, 10.0 and 11.0
    - With support for Unified Memory
- Debugging 64-bit CUDA programs
- Features and capabilities include
    - Support for dynamic parallelism
    - Support for MPI based clusters 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

TotalView CUDA Debugging Model



GPU Memory Hierarchy

- Hierarchical memory
  - Local (thread)
    - Local
    - Register
  - Shared (block)
  - Global (GPU)
    - Global
    - Constant
    - Texture
  - System (host)



Supported Type Storage Qualifiers

@generic	An offset within generic storage
@frame	An offset within frame storage
@global	An offset within global storage
@local	An offset within local storage
@parameter	An offset within parameter storage
@iparam	Input parameter
@oparam	Output parameter
@shared	An offset within shared storage
@surface	An offset within surface storage
@texsampler	An offset within texture sampler storage
@texture	An offset within texture storage
@rtvar	Built-in runtime variables
@register	A PTX register name
@sregister	A PTX special register name

Control of Threads and Warps

- Warps advance synchronously
  - They share a PC
- Single step operation advances all GPU threads in the same warp
- Stepping over a __syncthreads() call will advance all relevant threads
- To advance more than one warp
  - Continue, possibly after setting a new breakpoint
  - Select a line and “Run To”

Compiling for CUDA debugging

When compiling an NVIDIA CUDA program for debugging, it is necessary to pass the -g -G options to the nvcc compiler driver. These options disable most compiler optimization and include symbolic debugging information in the driver executable file, making it possible to debug the application.

```
% /usr/local/bin/nvcc -g -G -c tx_cuda_matmul.cu -o tx_cuda_matmul.o

% /usr/local/bin/nvcc -g -G -Xlinker=-R/usr/local/cuda/lib64 \
tx_cuda_matmul.o -o tx_cuda_matmul

% ./tx_cuda_matmul
A:
[ 0][ 0] 0.000000
...output deleted for brevity...
[ 1][ 1] 131.000000
```

Compiling for debugging

Compiling for Fermi
-gencode arch=compute_20,code=sm_20

Compiling for Fermi and Tesla
-gencode arch=compute_20,code=sm_20 –gencode arch=compute_10,code=sm_10

Compiling for Kepler
-gencode arch=compute_35,code=sm_35

Compiling for Pascal
-gencode arch=compute_60,code=sm_60

Compiling for Volta
-gencode arch=compute_70,code=sm_70

A TotalView Session with CUDA

A standard TotalView installation supports debugging CUDA applications running on both the host and GPU processors.

TotalView dynamically detects a CUDA install on your system. To start the TotalView GUI or CLI, provide the name of your CUDA host executable to the totalview or totalviewcli command.

For example, to start the TotalView GUI on the sample program, use the following command:

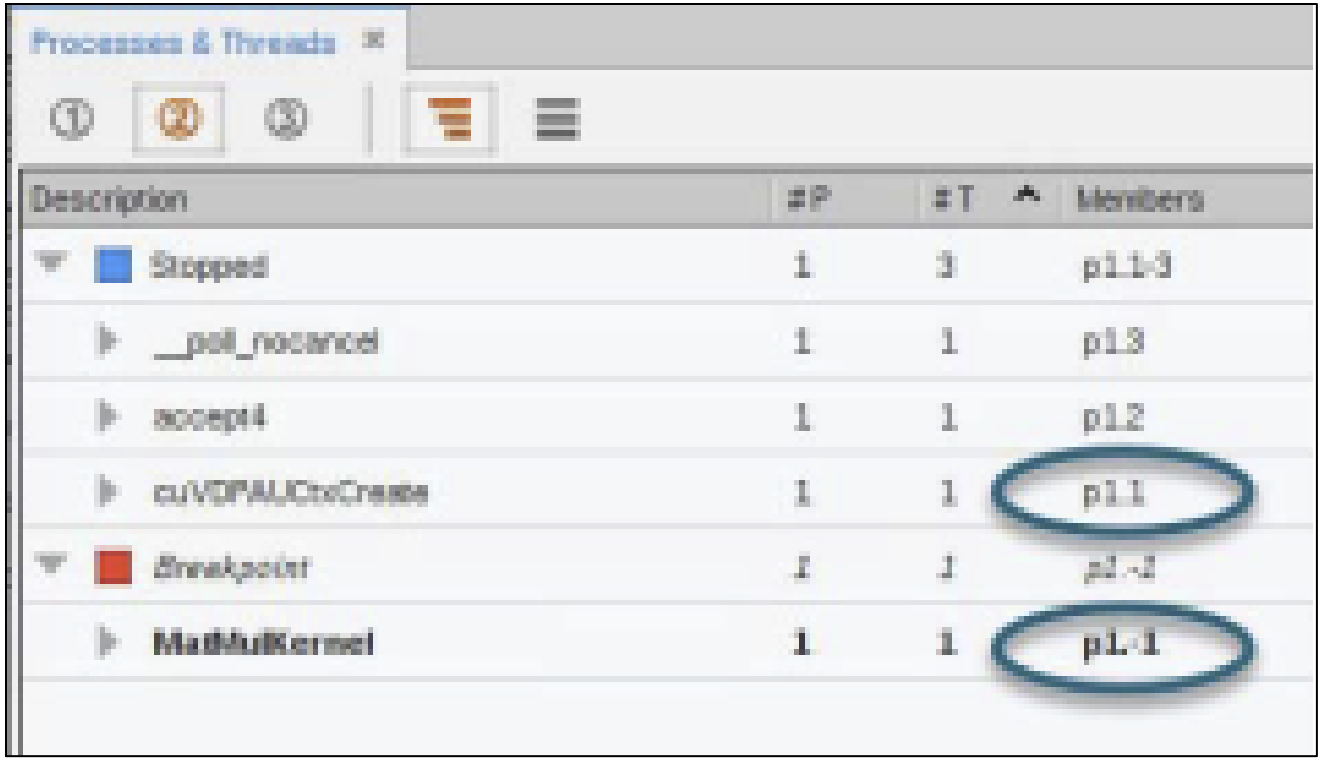
% totalview tx_cuda_matmul

Source View Opened on CUDA host code

Start Page | tx_cuda_matmul.cu

```
  for (int row = 0; row < height_; row++)
    for (int col = 0; col < width_; col++)
      A.elements[row * width_ + col] = row * 10.0 + col;
  return A;
}

static void
print_Matrix (Matrix A, const char *name)
{
  printf("%s:\n", name);
  for (int row = 0; row < A.height; row++)
    for (int col = 0; col < A.width; col++)
      printf ("[%5d][%5d] %f\n", row, col, A.elements[row * A.stride + co
}

// Multiply an m*n matrix with an n*p matrix results in an m*p matrix.
// Usage: tx_cuda_matmul [ m [ n [ p ] ] ]
// m, n, and p default to 1, and are multiplied by BLOCK_SIZE.
int main(int argc, char **argv)
{
//  cudaSetDevice(0);
  const int m = BLOCK_SIZE * (argc > 1 ? atoi(argv[1]) : 1);
  const int n = BLOCK_SIZE * (argc > 2 ? atoi(argv[2]) : 1);
  const int p = BLOCK_SIZE * (argc > 3 ? atoi(argv[3]) : 1);
  Matrix A = cons_Matrix(m, n);
  Matrix B = cons_Matrix(n, p);
  Matrix C = cons_Matrix(m, p);
  MatMul(A, B, C);
  print_Matrix(A, "A");
  print_Matrix(B, "B");
  print_Matrix(C, "C");
  return 0;
}
```

CUDA thread IDs and Coordinate Spaces



Host thread IDs have a positive thread ID (p1.1)
CUDA thread IDs have a negative thread ID (p1.-1)

GPU Physical and Logical Toolbars

Logical toolbar displays the Block and Thread coordinates.

Physical toolbar displays the Device number, Streaming Multiprocessor, Warp and Lane.

To view a CUDA host thread, select a thread with a positive thread ID in the Process and Threads view.

To view a CUDA GPU thread, select a thread with a negative thread ID, then use the GPU thread selector on the logical toolbar to focus on a specific GPU thread.

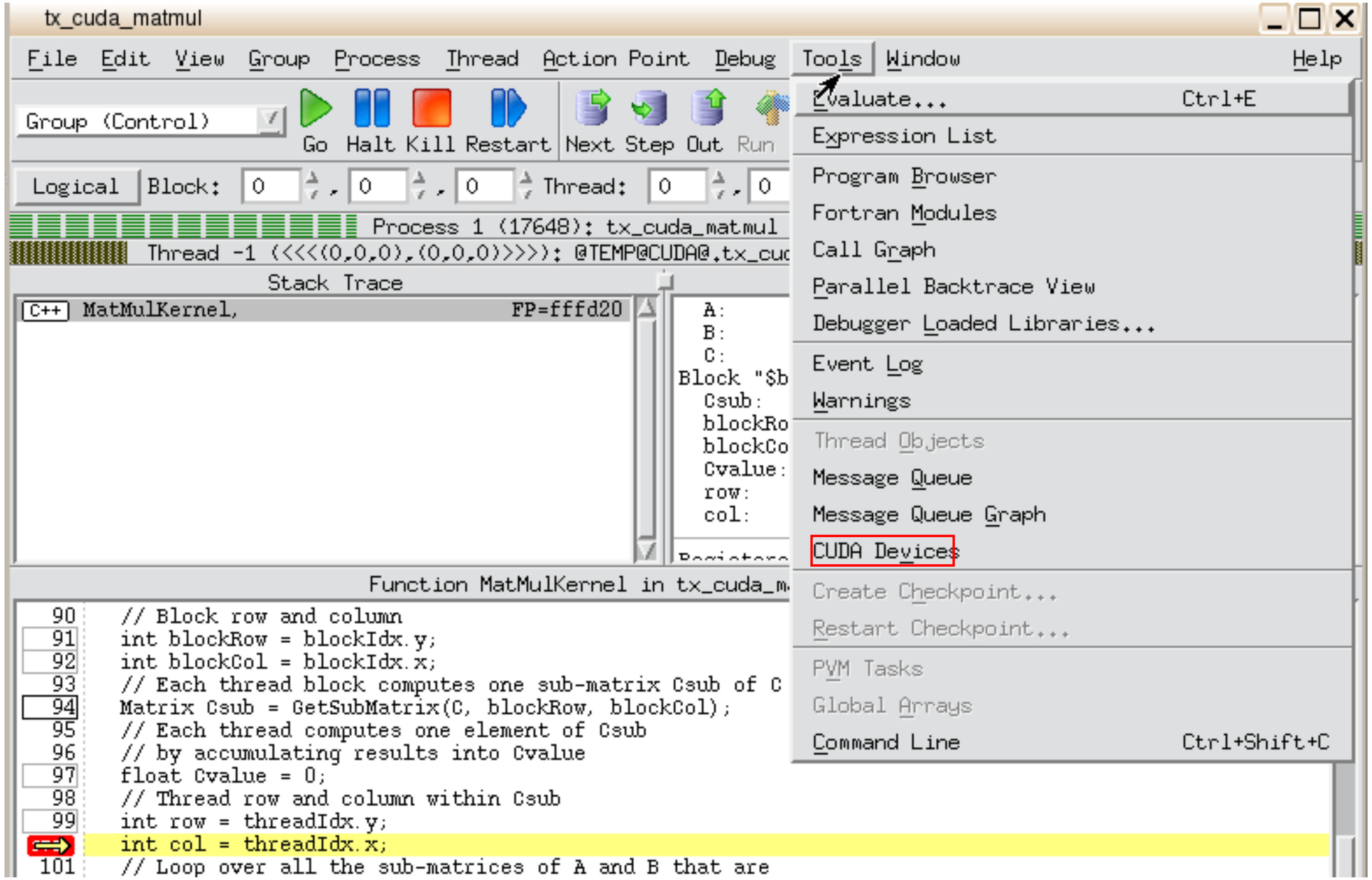
Displaying CUDA Program Elements

- The identifier @local is a TotalView built-in type storage qualifier that tells the debugger the storage kind of "A" is local storage.
- The debugger uses the storage qualifier to determine how to locate A in device memory

The CUDA Devices Window

Classic UI Only

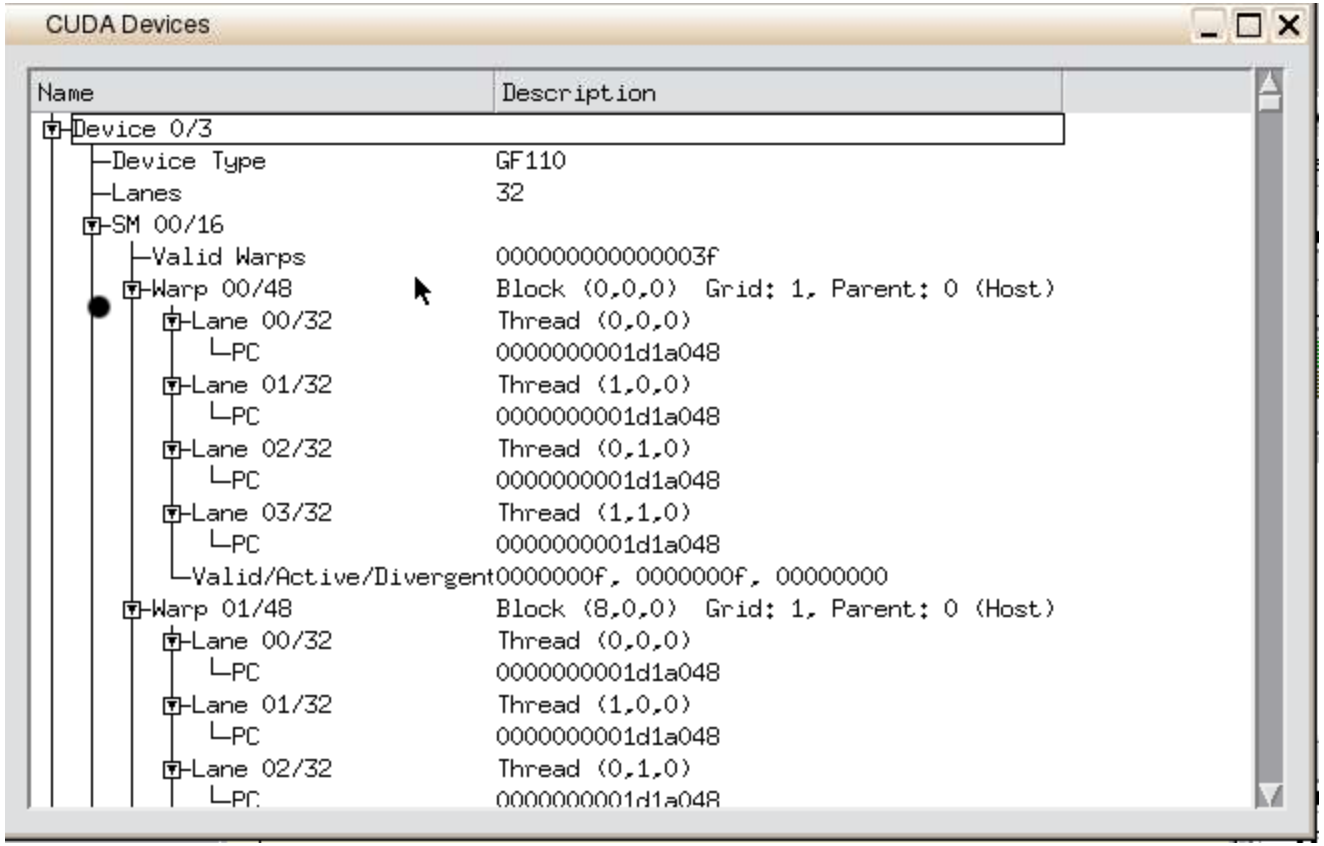
We can get an idea of what physical cards are accessible and what threads we can access with the CUDA devices window



The CUDA Devices Window

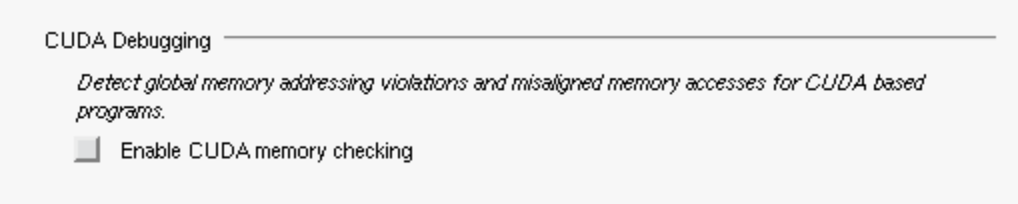
- The devices window shows us the type of device, the number of lanes available and the active SM's, warps and lanes

Classic UI Only



CUDA Memory Checker Feature

Classic UI Only

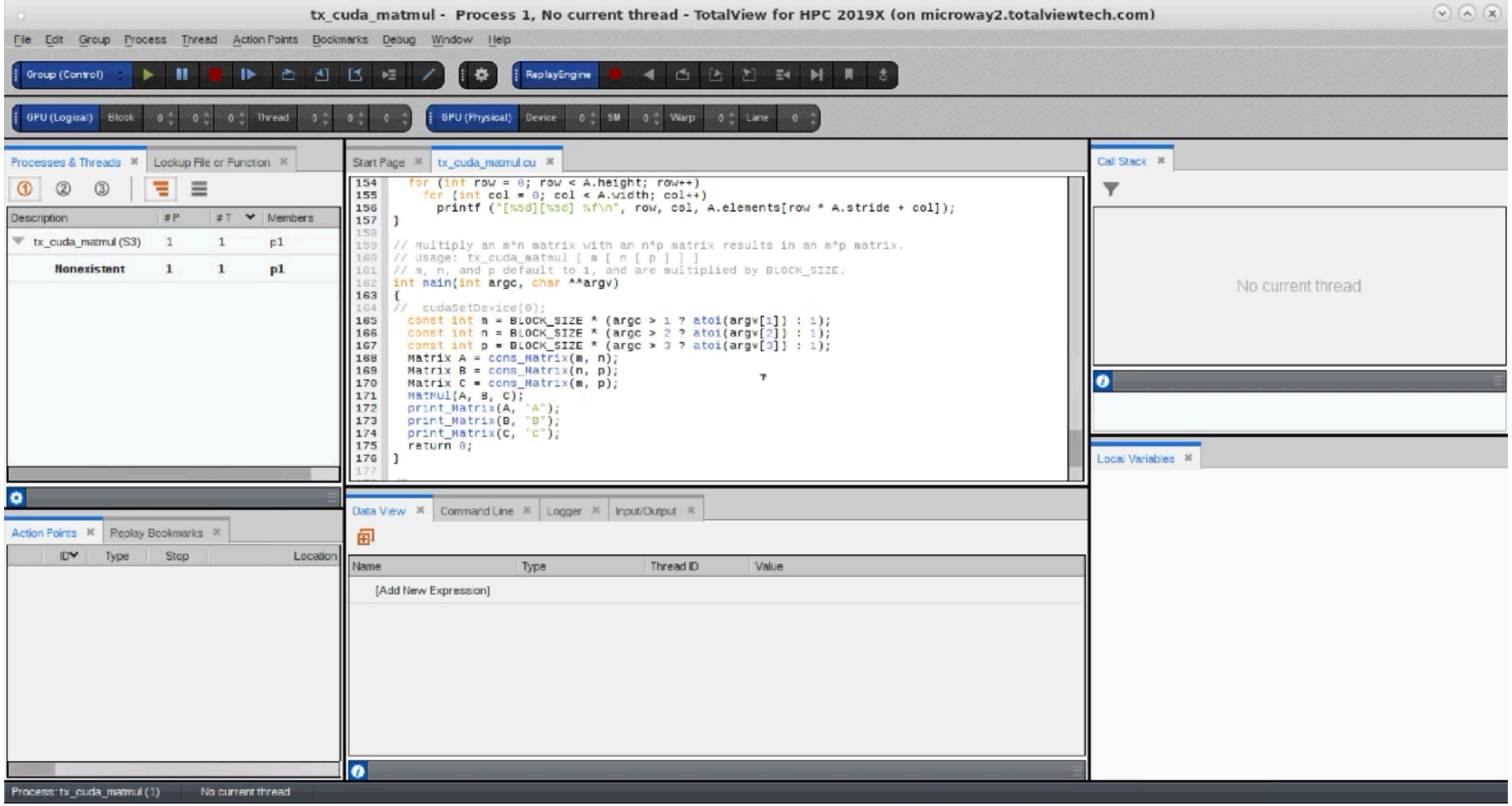


To enable CUDA memory checking in the new UI :

- Pass the -cuda_memcheck option to the totalview command, for example:
  totalview -cuda_memcheck

- Set the TV::cuda_memcheck CLI state variable to true. For example:
  dset TV::cuda_memcheck true

Demo


tx_cuda_matmul - Process 1, No current thread - TotalView for HPC 2019X (on microway2.totalviewtech.com)
File Edit Group Process Thread Action Points Bookmarks Debug Window Help
Group (Control)
ReplayEngine
GPU (Logical) Block Thread
GPU (Physical) Device SM Warp Lane
Processes & Threads
Lookup File or Function
Description #P #T Members
tx_cuda_matmul (S3) 1 1 p1
Nonexistent 1 1 p1
Start Page
tx_cuda_matmul.cu
for (int row = 0; row < A.height; row++)
for (int col = 0; col < A.width; col++)
printf ("[%5d][%5d] %f\n", row, col, A.elements[row * A.stride + col]);
}
// Multiply an m*n matrix with an n*p matrix results in an m*p matrix.
// Usage: tx_cuda_matmul [m [n [p]]]
// m, n, and p default to 1, and are multiplied by BLOCK_SIZE.
int main(int argc, char **argv)
{
// cudaSetDevice(0);
const int m = BLOCK_SIZE * (argc > 1 ? atoi(argv[1]) : 1);
const int n = BLOCK_SIZE * (argc > 2 ? atoi(argv[2]) : 1);
const int p = BLOCK_SIZE * (argc > 3 ? atoi(argv[3]) : 1);
Matrix A = cons_Matrix(m, n);
Matrix B = cons_Matrix(n, p);
Matrix C = cons_Matrix(m, p);
MatMul(A, B, C);
print_Matrix(A, "A");
print_Matrix(B, "B");
print_Matrix(C, "C");
return 0;
}
Call Stack
No current thread
Local Variables
Action Points
Replay Bookmarks
ID Type Stop Location
Data View
Command Line
Logger
Input/Output
Name Type Thread ID Value
[Add New Expression]
Process: tx_cuda_matmul (1)
No current thread

Debugging with TotalView’s CLI

TotalView's CLI

- TotalView's CLI is a TCL based command line interface providing full access to the debugger
- Accessible through:
  - *Tools | Command Line* menu in Classic UI
  - Command Line view in new UI
  - Directly by running `totalviewcli`
- Using the CLI in the TotalView Reference Guide provides comprehensive documentation on all the CLI commands and options
  - http://docs.roguewave.com/totalview/current/html/index.html#page/Reference_Guide%2Ftotalviewref-part1.html

Using the CLI to examine data

dgo

Resumes execution of target process

dhalt

Suspends execution of target process

dhelp

Lists the available commands

dlist

Displays code relevant to current location

dnext

Steps source lines, stepping over subroutines

Using the CLI to examine data (2)

dprint

Prints the value of a variable or an expression

dstatus

Displays an aggregated view of the current processes and threads

dstep

Steps lines, stepping into subroutines

dwhat

Displays information about a symbol

dwhere

Displays locations in the call stack

Demo

- CLI Demo (combined example)

Batch Debugging with TVScript

tvscript

- A straightforward language for unattended and/or batch debugging with TotalView and/or MemoryScape
- Usable whenever jobs need to be submitted or batched
- Can be used for automation
- A more powerful version of printf, no recompilation necessary between runs
- Schedule automated debug runs with *cron* jobs
- Expand its capabilities using TCL

tvscript

tvscript [*options*] [*filename*] [-a *program_args*]

options

TotalView and tvscript command-line options.

filename

The program being debugged.

-a *program_args*

Program arguments.

tvscript

- All of the following information is provided by default for each print
  - Process id
  - Thread id
  - Rank
  - Timestamp
  - Event/Action description
- A single output file is written containing all of the information regardless of the number of processes/threads being debugged

Supported tvscript events

Event Type	Event	Definition
General event	**any_event**	A generated event occurred.
Memory debug-ging event	**addr_not_at_start**	Program attempted to free a block using an incorrect address.
	alloc_not_in_heap	The memory allocator returned a block not in the heap; the heap may be corrupt.
	alloc_null	An allocation either failed or returned NULL; this usu-ally means that the system is out of memory.
	alloc_returned_bad_alignment	The memory allocator returned a misaligned block; the heap may be corrupt.
	any_memory_event	A memory event occurred.
	bad_alignment_argument	Program supplied an invalid alignment argument to the heap manager.
	double_alloc	The memory allocator returned a block currently being used; the heap may be corrupt.
	double_dealloc	Program attempted to free an already freed block.
	free_not_allocated	Program attempted to free an address that is not in the heap.
	guard_corruption	Program overwrote the guard areas around a block.

Supported tvscript events

Event Type	Event	Definition
	hoard_low_memory_threshold	Hoard low memory threshold crossed.
	realloc_not_allocated	Program attempted to reallocate an address that is not in the heap.
	rz_overrun	Program attempted to access memory beyond the end of an allocated block.
	rz_underrun	Program attempted to access memory before the start of an allocated block.
	rz_use_after_free	Program attempted to access a block of memory after it has been deallocated.
	rz_use_after_free_overrun	Program attempted to access memory beyond the end of a deallocated block.
	rz_use_after_free_underrun	Program attempted to access memory before the start of a deallocated block.
	termination_notification	The target is terminating.
Source code debugging event	**actionpoint**	A thread hit an action point.
	error	An error occurred.
Reverse debugging	**stopped_at_end**	The program is stopped at the end of execution and is about to exit.

Supported tvscript actions

Action Type	Action	Definition
Memory debugging actions	**check_guard_blocks**	Checks all guard blocks and write violations into the log file.
	list_allocations	Writes a list of all memory allocations into the log file.
	list_leaks	Writes a list of all memory leaks into the log file.
	save_html_heap_status_source_view	Generates and saves an HTML version of the Heap Status Source View Report.
	save_memory_debugging_file	Generates and saves a memory debugging file.
	save_text_heap_status_source_view	Generates and saves a text version of the Heap Status Source View Report.
Source code debugging actions	**display_backtrace** [**-level***level-num*] [*num_levels*] [*options*]	Writes the current stack backtrace into the log file. **-level** *level-num* sets the level at which information starts being logged. *num_levels* restricts output to this number of levels in the call stack. If you do not set a level, **tvscript** displays all levels in the call stack. *options* is one or more of the following: **-[no]show_arguments** **-[no]show_f**p **-[no]show_fp_registers** **-[no]show_image** **-[no]show_locals** **-[no]show_pc** **-[no]show_registers**

Supported tvscript actions

Action Type	Action	Definition
	print [**-slice** {*slice_exp*}] {*variable* | *exp*}	Writes the value of a variable or an expression into the log file. If the variable is an array, the **-slice** option limits the amount of data defined by slice_exp. A slice expression is a way to define the slice, such as **var[100:130]**in C and C++. (This displays all values from **var[100]**to **var[130]**.) To display every fourth value, add an additional argument; for exam-ple,**var[100:130:4]**. For additional information, see *"Examining Arrays"*in the *TotalView for HPC User Guide*.
Reverse debug-ging actions	**enable_reverse_debugging**	Turns on ReplayEngine reverse debugging and begins recording the execution of the program.
	save_replay_recording_file	Saves a ReplayEngine recording file. The file-name is of the form `<ProcessName>-<PID>_<DATE>.<INDEX>.recording`.

tvscript examples

Simple example

```
tvscript \
-create_actionpoint "method1=>display_backtrace -show_arguments" \
-create_actionpoint "method2#37=>display_backtrace \
              -show_locals -level 1" \
-event_action "error=>display_backtrace -show_arguments \
              -show_locals" \
-display_specifiers "noshow_pid,noshow_tid" \
-maxruntime "00:00:30" \
~/work/filterapp /filterapp -a 20
```

MPI example

```
tvscript -mpi "Open MPI" -tasks 4 \
-create_actionpoint \
"hello.c#14=>display_backtrace" \
~/tests/MPI_hello
```

tvscript examples

Memory Debugging example

```
tvscript -maxruntime "00:00:30" \
-event_action "any_event=save_memory_debugging_file" \
-guard_blocks -hoard_freed_memory -detect_leaks \
~/work/filterapp -a 20
```

ReplayEngine example

```
tvscript \
-create_actionpoint "main=>enable_reverse_debugging" \
-event_action "stopped_at_end=>save_replay_recording_file" \
filterapp
```

Demo

- TVScript demo (tvscript –script_file file tvscript_example.tvd ex2)

TotalView Roadmap

Recent TotalView Release Features (2020)

- **2020.3 (Nov 2020)**
  - TotalView Remote UI
  - OpenMP Debug API v5.0 support
  - TotalView Student license changes
  - GCC 10, Fedora 32, Ubuntu 20.04
- **2020.2 (Sep 2020)**
  - CUDA 11 support
  - Remote Display Client updated
  - TotalView Solaris platform ported to 64 bits
  - “Dive-in-all” to view a structure member across an array
  - Easily focus on specific data in new data views
- **2020.1 (May 2020)**
  - TotalView FlexNet Publisher License update
  - macOS Catalina support
  - TotalView stepping and local variable view performance updates
  - Array statistics view auto update
  - FlexNet Embedded failover server support
- **2020 (Feb 2020)**
  - Display thread names and lightweight process IDs
  - Array statistics view
  - Rebranding to use “TotalView by Perforce” logo

Common TotalView Usage Hints

Common TotalView Usage Hints

- TotalView can’t find the program source
  - Did you compile with -g ?
  - How to adjust the TotalView search paths? Preferences -> Search Path
- Python Debugging
  - Making sure proper system debug packages are installed for Python
- X11 forwarding performance
  - If users are forwarding X11 displays through ssh TotalView UI performance can be bad
- Understanding different ways to stop program execution with TotalView Action Points
  - Using a watchpoint on a local variable
- Focus
  - Diving on a variable that is no longer in scope. Check the Local Variables window for in scope variables
  - Totalview doesn’t change focus to the thread hitting a breakpoint. Set Action Point Preferences to “Automatically focus on threads/processes at breakpoint”

Common TotalView Usage Hints (cont.)

- MPI Debugging
  - Differences in launching MPI job from within the TotalView UI vs the command line.
  - TotalView runs an MPI program without stopping. Set the Parallel Preferences to “Ask What To Do” in After Attach Behavior
  - Using wrong attributes in processes and threads view
- Reverse Debugging
  - Running out of memory by not setting the maximum memory allocated to ReplayEngine
  - Defer turning on reverse debugging until later in program execution to avoid slow initialization phases
  - Adjust reverse debugging circular buffer size to reduce resources
- Memory Debugging
  - Starting with All memory debugging options enabled rather than Low
  - Not setting a size restriction for Red Zones
  - Issues with getting memory debugging turned on in an MPI job. May have to set LD_PRELOAD environment variable or worst case, prelink HIA

Common TotalView Usage Hints (cont.)

- Differences in functionality between new UI and classic UI
  - How to switch between them. Preferences -> Display or totalview –newUI and totalview -oldUI
  - Where the gaps still are in functionality
- Reverse Connect with tvconnect
  - When I use Reverse Connect I get the following obscure message: myProgram *is an invalid or incompatible executable file format for the target platform*
  - The message indicates an incompatible file format but most often this occurs if the program provided to tvconnect for TotalView to debug cannot be found. The easiest way to resolve problem is to provide the full path to the target application, e.g., *tvconnect /home/usr/myProgram*
- How do I get help?
  - How to submit a support ticket? techsupport@roguewave.com
  - Where is TV documentation (locally and on the internet). https://help.totalview.io/
  - Are there videos I can watch to learn how to use TotalView? https://totalview.io/support/video-tutorials

LBL/NERSC - TotalView Usage Hints

LBL/NERSC TotalView Usage Hints

- Remote UI
    - Configure cori.nersc.gov Remote UI:
        - Connection Name: cori.nersc.gov
        - Remote Host(s): username@cori.nersc.gov
        - TotalView Remote Installation Directory: /usr/common/software/toolworks/totalview.default/bin
    - For now, load TotalView modules needed in your .bash_profile.ext
        - module load totalview
- Use Reverse Connect (tvconnect) to easily connect back and launch applications/jobs
    - tvconnect stays active until user detaches from the UI or ctrl-c tvconnect once done
    - Batch Submission with sbatch:
        - !/bin/bash
          #SBATCH --qos=debug
          #SBATCH --time=5
          #SBATCH --nodes=1
          #SBATCH --tasks-per-node=4
          #SBATCH --constraint=haswell
          module load openmpi
          tvconnect srun primeCount
    - Pre-allocated node – make sure to use full paths
        - **tvconnect** `which srun` -n 4 `pwd`/primeCount

Q&A

Contact us

- Bill Burns (Senior Director of Product Development and Product Manager)

  bburns@perforce.com

- Dean Stewart (Senior Sales Engineer)

  dstewart@perforce.com