### parallel tools platform http://eclipse.org/ptp

### Developing Scientific Applications with the IBM Parallel Environment Developer Edition

Greg Watson, IBM grw@us.ibm.com

Christoph Pospiech, IBM christoph.pospiech@de.ibm.com

#### ScicomP '13 May 2013

Portions of this material are supported by or based upon work supported by the Defense Advanced Research Projects Agency (DARPA) under its Agreement No. HR0011-07-9-0002, the United States Department of Energy under Contract No. DE-FG02-06ER25752



# **Tutorial Highlights**

Provides a brief introduction to Eclipse
Shows how to import existing code into Eclipse
Shows how to build and run an MPI application
Shows features of PE Developer Environment:

Monitoring hardware performance counters
Profiling/tracing and MPI application
Profiling I/O activity in an application

Shows debugging with the IBM Parallel Debugger



# **Tutorial Outline**

parallel tools platform

Time	Module	Topics
13:30 - 14:00	1. Overview of Eclipse and PTP	<ul> <li>Introduction to Eclipse/PTP</li> <li>Installation of Parallel Package</li> </ul>
14:00 - 15:00	2. Eclipse Basics	<ul> <li>Importing a project</li> <li>Editing, building, launching</li> <li>Working with MPI, Fortran</li> </ul>
15:00 - 15:30	Break	
15:30 - 16:00	3. Advanced Features	<ul> <li>Target system configurations</li> <li>Advanced development and refactoring</li> </ul>
16:00 - 16:30	4. IBM HPC Toolkit	<ul> <li>Profile application using Xprof</li> <li>Hardware performance counters</li> <li>MPI Profiling and Tracing</li> </ul>
16:30 - 16:55	5. IBM Parallel Debugger	<ul> <li>Overview of features</li> <li>Hands-on workshop exercises</li> </ul>
16:55 - 17:00	6. Wrap-up	<ul> <li>Overview of features not covered</li> <li>Resources, getting questions answered</li> <li>How to participate</li> <li>Participant feedback</li> </ul>

# Installation

✦ Objective

To learn how to install Eclipse and PTP

Contents

- System Prerequisites
- Download and Install Eclipse

### System Prerequisites

Local system (running Eclipse) Linux (just about any version) MacOSX (10.5 Leopard or higher) Windows (XP on) Java: Eclipse requires Sun or IBM Java Only need Java runtime environment (JRE) + Java 1.6 or higher +Java 1.6 is the same as JRE 6.0 The GNU Java Compiler (GCJ), which comes standard on Linux, will not work! OpenJDK, distributed with some Linux distributions, has not been tested by us but should work.

See http://wiki.eclipse.org/PTP/installjava

### Eclipse Packages

- The current version of Eclipse (4.2) is also known as "Juno"
  - Next release "Kepler" in June 2013
- Eclipse is available in a number of different packages for different kinds of development
  - http://eclipse.org/downloads
- For PTP, we recommend the all-in-one download:
  - Eclipse for Parallel Application Developers



Eclipse for Parallel Application Developers, Downloaded 97,861 Times Details

### We often call this the "Parallel Package"

Installation

### Pre-release Package

- For this tutorial we will be using a pre-release version of Eclipse "Kepler"
- This version will be released at the end of June
- The Parallel Package is available from the "Developer Builds" link on the main downloads page
  - http://eclipse.org/downloads



Installation

Install-3



### Exercise

- 1. Go to the "Developer Builds" page of the main Eclipse download site
- 2. Download the "Eclipse for Parallel Application Developers" package to your laptop
  - Your tutorial instructions will provide the location of the package
  - Make sure you match the architecture with that of your laptop
- 3. If your machine is Linux or Mac OS X, untar the file
  - On Mac OS X you can just double-click in the Finder
- 4. If your machine is Windows, unzip the file
- 5. This creates an **eclipse** folder containing the executable as well as other support files and folders

## Starting Eclipse

### + Linux

From a terminal window, enter "<eclipse\_installation\_path>/eclipse/eclipse &"

### + Mac OS X

- + From finder, open the **eclipse** folder where you installed
- Double-click on the Eclipse application
- Or from a terminal window

#### Windows

- Open the eclipse folder
- Double-click on the eclipse executable



c) Copyright Eclipse contributors and others, 2000, 2012. All rights reserved. Eclipse ; a trademark of the Eclipse Foundation, Inc. Oracle and Java are registered trademarks f Oracle and/or its affiliates. Other names may be trademarks of their respective owners.

Install-6

# Specifying A Workspace

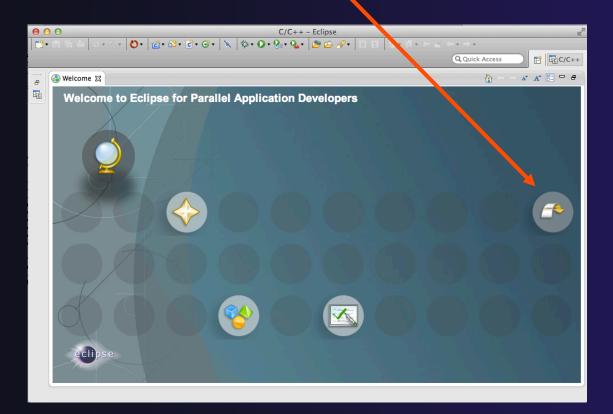
- Eclipse prompts for a workspace location at startup time
- The workspace contains all user-defined data
  - Projects and resources such as folders and files
  - The default workspace location is fine for this tutorial

The prompt can be turned off	Workspace Launcher         Select a workspace         Eclipse stores your projects in a folder called a workspace.         Choose a workspace folder to use for this session.
	Workspace: /Users/beth/Documents/workspace ▼ Browse □ Use this as the default and do not ask again
	Cancel OK

Installation

# Eclipse Welcome Page

### Displayed when Eclipse is run for the first time Select "Go to the workbench"



Installation

Install-7

# Introduction

Objective

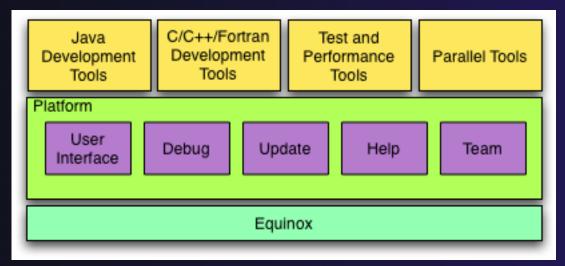
To introduce the Eclipse platform and PTP

Contents

- New and Improved Features
- + What is Eclipse?
- ✤ What is PTP?

# What is Eclipse?

- A vendor-neutral open-source workbench for multi-language development
- A extensible platform for tool integration
- Plug-in based framework to create, integrate and utilize software tools



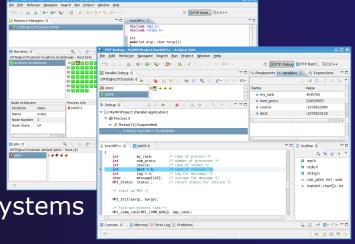
Introduction

# **Eclipse Features**

- Full development lifecycle support
- Revision control integration (CVS, SVN, Git)
- Project dependency management
- Incremental building
- Content assistance
- Context sensitive help
- Language sensitive searching
- Multi-language support
- Debugging

# Parallel Tools Platform (PTP)

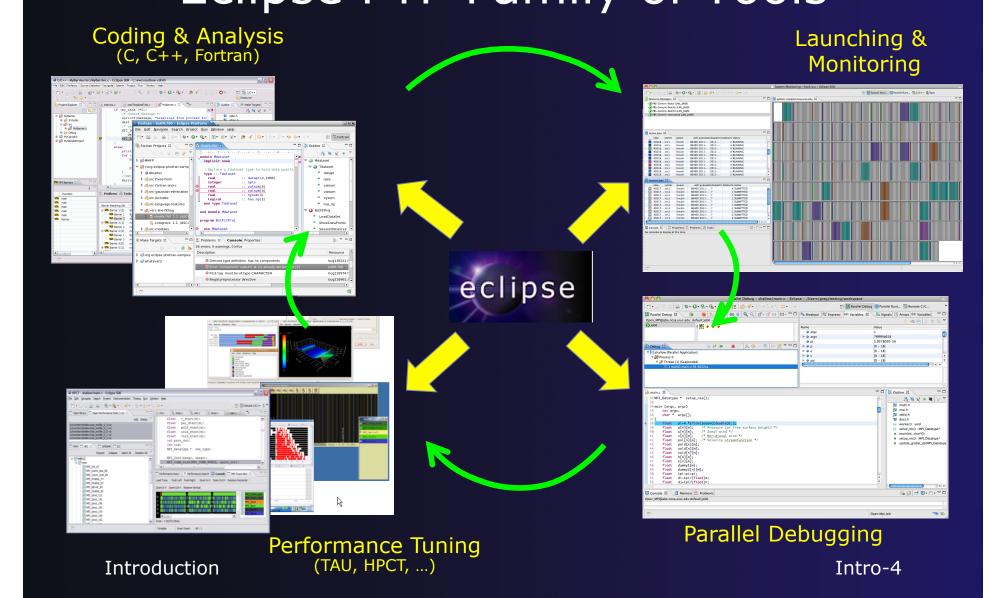
- The Parallel Tools Platform aims to provide a highly integrated environment specifically designed for parallel application development
- Features include:
  - An integrated development environment (IDE) that supports a wide range of parallel architectures and runtime systems
  - + A scalable parallel debugger
  - Parallel programming tools (MPI, OpenMP, UPC, etc.)
  - Support for the integration of parallel tools
  - An environment that simplifies the end-user interaction with parallel systems
- http://www.eclipse.org/ptp



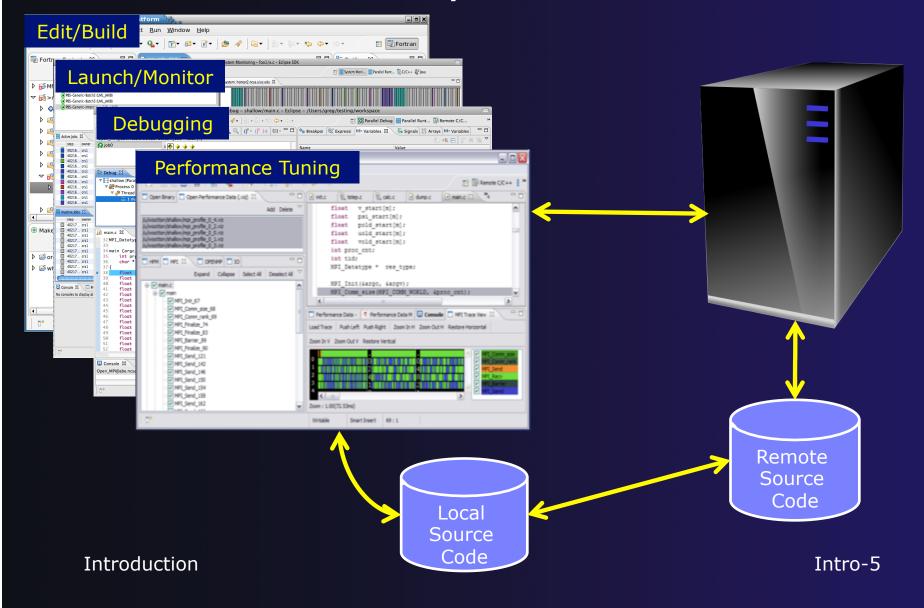
Introduction

# Eclipse PTP Family of Tools

parallel tools platform



# How Eclipse is Used





### Parallel Environment Developer Edition 1.3

	Programming models	HPC Toolkit	Parallel Tools Platform	<b>Base Tools Platform</b>	indows
PE DE Client	<ul> <li>MPI</li> <li>LAPI</li> <li>PAMI</li> <li>UPC</li> <li>OpenMP</li> <li>OpenSHMEM</li> </ul>	<ul> <li>MPI profiling</li> <li>OpenMP profiling*</li> <li>Hardware counter profiling</li> <li>I/O profiling</li> <li>Profiling and trace visualization</li> <li>Binary instrumentation*</li> </ul>	<ul> <li>PTP 7.0</li> <li>Parallel Language Development Tools</li> <li>Parallel application launch</li> <li>System monitoring</li> <li>Synchronized projects</li> <li>Remote projects</li> <li>External Tools Framework</li> <li>LSF Support</li> </ul>	Eclipse Platform (4.3) C/C++ Development Tools (CDT 8.2) Fortran Development Tools (Photran 8.1) Linux Tools	Mae OS X Linux Wi

DE rver	НР			
PE I Serv	Peekperf VisualizationInstrumentation LibrariesCommand-line Tools		and-line Tools Open MPI	inux
PE RE	Scalable Communic	MPICH2 PBS/Torque	E	
PE	POF	SLURM Grid Engine		
	LoadLeveler	LoadLeveler LSF		AIX
	Power	x86 BG/Q		

### http://ibm.co/12L2RxK

IBM-0

# Importing a Project

### Objective

Learn how to import a project into Eclipse

Learn how to manage synchronized projects

### Contents

- Eclipse project locations
- Creating a synchronized project
- Managing synchronized project properties
- Using synchronize filters

# **Project Location**

### + Local

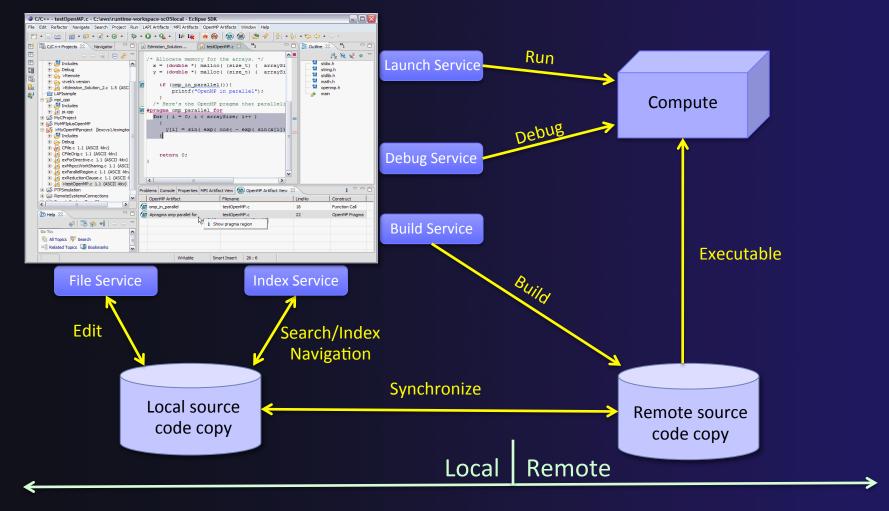
Source is located on local machine, builds happen locally

This is the default Eclipse model

### Synchronized

- Source is located on both local and remote machine(s), then kept in synchronization by Eclipse
- Building and launching happens remotely (can also happen locally)
- Used mainly for scientific and supercomputing applications
- There are also remote-only projects, but these have limitations and are not covered here

# Synchronized Projects



Synchronized Projects

Sync-2

# Revision Control Systems (RCS)

- Eclipse supports a range of RCS, such as CVS, Git, and Subversion (and others)
- These are distinct from synchronized projects
- RCS can be used in conjunction with synchronized projects
- Synchronized projects are typically not used for revision control

# Synchronized Project Creation

### Local -> Remote

- Projects start out local then are synchronized to a remote machine
- Three options
  - Created from scratch
  - Imported from local filesystem
  - Imported from RCS
- Remote -> Local
  - Projects start out on remote machine then are synchronized to the local system
  - Two options
    - + Already on remote system
    - Checked out from RCS

# Source Code for project

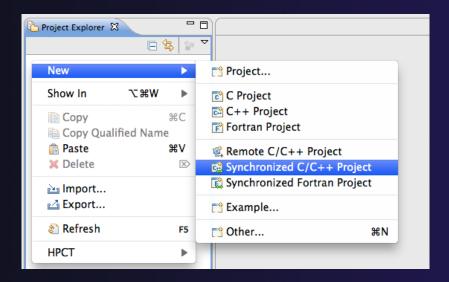
Source code exists on remote target

```
$ pwd
/qpfs/ibmu/tibbitts/shallow
$ ls -la
total 2880
drwxr-xr-x 2 tibbitts users 32768 Mar 16 15:53 .
drwxr-xr-x 7 tibbitts users 32768 Mar 15 18:38 ...
   -r--r-- 1 tibbitts users 1741 Feb 11 16:25 calc.c
-rw
-rw-r--r-- 1 tibbitts users 2193 Feb 11 16:25 copy.c
-rw-r--r-- 1 tibbitts users 2873 Jan 25 08:52 decs.h
-rw-r--r-- 1 tibbitts users 2306 Feb 11 16:25 diag.c
   -r--r-- 1 tibbitts users 2380 Feb 11 16:25 dump.c
-rw
-rw-r--r-- 1 tibbitts users 2512 Feb 11 16:25 init.c
   -r--r-- 1 tibbitts users 6161 Mar 15 19:27 main.c
-rw-
-rw-r--r-- 1 tibbitts users 718 Mar 15 18:34 Makefile
-rw-r--r-- 1 tibbitts users 1839 Feb 11 16:25 time.c
-rw-r--r-- 1 tibbitts users 2194 Feb 11 16:25 tstep.c
-rw-r--r-- 1 tibbitts users 8505 Feb 11 16:25 worker.c
Ś.
```

# Create Synchronized Project

#### In the Project Explorer, right click then choose

+ New>Synchronized C/C++ Project if your project is C/C++ only



- New>Synchronized Fortran Project if your project contains Fortran files
- + This adds a Fortran nature so you can access Fortran properties, etc.

Synchronized Projects

parallel tools platform

# New Synchronized Project Wizard

Enter the **Project Name** + E.g. "shallow" The Local Directory specifies where the local files are located + Leave as default The Remote Directory specifies where the remote files are located Select a connection to the remote machine, or click on **New...** to create a new one (See next slide) + Browse for the directory on the remote machine Use **Modify File Filtering...** if required (see later slide)

$\Theta \cap \Theta$	New Synchronized Project	-
New Synchronized P Project name must be	7	c
Project name:		_
Local directory		
		_
Local directory:	Browse	-
Remote directory		
Connection name:	Please select a connection	$\triangleright$
Remote directory:	Browse	
Modify file filtering.		
Project Type	Remote Toolchain (select 1 or more)	
GNU Autotools	ls	
Executable		
Executable (XL		
<ul> <li>General Control</li> <li>Control</li> <li>Control<!--</th--><th>· · · · · · · · · · · · · · · · · · ·</th><th></th></li></ul>	· · · · · · · · · · · · · · · · · · ·	
Static Library		
Static Library (		
Executable (XL)		
Static Library(X		
Shared Library		
Executable (XL)	L UPC)	

Synchronized Projects

# Creating a Connection

# In the Target Environment Configuration dialog

- Enter a Target name for the remote host
- Enter host name, user name, and user password or other credentials
- + Select Finish

00	Target Environment Configuration
Generic Remote Hos	t i i i i i i i i i i i i i i i i i i i
Properties for connect	ing to a generic host
Target name: trestles	
Host Information	
🔵 Localhost 💿 Rei	note host
Host: trestles.sdsc.	edu
User: train14	
Password based a	uthentication
Password:	•••
O Public key based	authentication
File with private key:	Browse
Passphrase:	
	Advanced
?	Cancel Finish
	Sync-8

# Project Type & Toolchain

?

#### Choose the Project Type

- If you are synchronizing with an existing project, use Makefile Project>Empty Project
- Otherwise, choose the type of project you want to create
- Choose the toolchain for the remote build
  - Use a toolchain that most closely matches the remote system
- Choose a toolchain for the local build
  - This is used for advanced editing/ searching
- Click Finish to create the project

roject Type	Remote Toolchain (select 1 or more)
Executable	Cross GCC
Executable (XL UPC)	Cygwin GCC
Shared Library	GCC Fortran
Shared Library (XL UPC)	GNU Autotools Toolchain IBM XL Fortran Tool Chain
Static Library	Intel(R) Fortran Toolchain on IA-32
Static Library (XL UPC)	Intel(R) Fortran Toolchain on IA-64
Executable (XL C/C++)	Intel(R) Fortran Toolchain on Intel(R) 64
Static Library(XL C/C++)	Linux Berkeley UPC
Shared Library (XL C/C++)	Linux GCC
Executable (XL UPC)	MacOSX Berkeley UPC
Static Library(XL UPC)	MacOSX GCC
Shared Library (CC UPC)	Local Toolchain (optional - select 0 or more)
Executable (Gnu Fortran on Linux/*nix)	Other Toolchain
Executable (Gnu Fortran on MacOS X)	Cross GCC
Executable (Gnu Fortran on Windows)	Cygwin GCC
Static Library (Intel(R) Fortran)	GCC Fortran
Executable (Intel(R) Fortran)	GNU Autotools Toolchain
Shared Library (Intel(R) Fortran)	IBM XL Fortran Tool Chain
Evecutable (IBM XL Fortran)	Intel(R) Fortran Toolchain on IA-32
V > Maxefile project	Intel(R) Fortran Toolchain on IA-64 Intel(R) Fortran Toolchain on Intel(R) 64
Empty Project	Linux Berkeley UPC
Hello World C++ Makefile Project	Linux GCC
Empty Project - Fortran	MacOSX Berkeley UPC
Demo – Hello World – Fortran	MacOSX GCC
Show project types and toolchains only if the	v are supported on the platform
show project types and toolchains only if the	y are supported on the platform

< Back

Next >

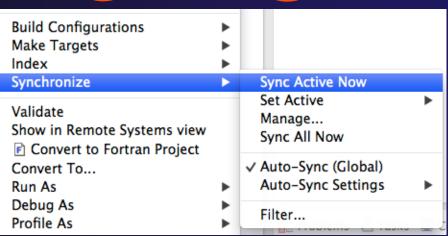
parallel tools platform

Finish

Cancel

# Synchronized Project Menu

- Synchronized projects are indicated with a "synchronized" icon
- Right click on project to access
   Synchronize menu
  - Sync Active Now will manually synchronize the active configuration
  - Set Active can be used to select the active configuration
  - Manage... is used to create new configurations to synchronize to different target systems
  - Sync All Now will manually synchronizes all configurations



 Auto-Sync (Global) will enable or disable automatic synchronization

shallow

- Auto-Sync Settings can be used to select which configurations will be synchronized
- Filter... is used to change the filter settings for the project

Synchronized Projects

Sync-10

shallow

# Manage Configurations

- Used to manage synchronize configurations
- Use Set Active to change the active configuration (shown in **bold** in the list of configurations)
- Use Add to add a new configuration in order to synchronize to a different target system
- Other configuration information, such as the default build configuration, can also be changed

0	O O Configure Synchronize Project Filters				
_					
	ocal		Add		
	estles		Remove		
			Set Active		
CD	T Build Configuration	15			
De	fault Configuration:	Default_with_Linux_GC	:C +		
		Cancel	ОК		

By default, there will be a configuration for the target system (active) and a **Local** configuration. The Local configuration can be used to build a local copy of the project if desired.

Synchronized Projects

# Synchronize Filters

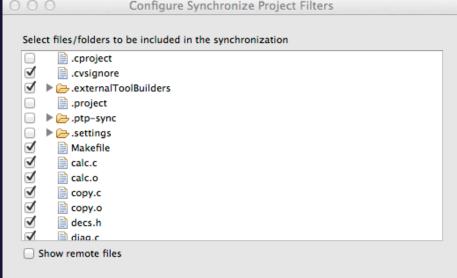
 If not all files in the remote project should be synchronized, a filter can be set up

- For example, it may not be desirable to synchronize binary files, or large data files
- Filters can be created at the same time as the project is created
  - Click on the Modify File Filtering... button in the New Project wizard
- Filters can be added later
  - Right click on the project and select
     Synchronizee>Filter...

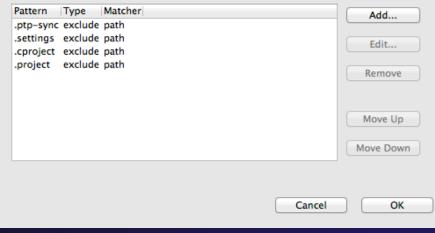
# Synchronize Filter Dialog

- Files can be filtered individually by selecting/unselecting them in the File View
- Include or exclude files based on
  - Paths
  - Regular expressions
  - Wildcards (foo.\*)

00	Add Pattern
Pattern:	
Matcher	Туре
💿 Path	○ Regex ○ Wildcard
Pattern T	Туре
OInclu	de 💿 Exclude
	Cancel OK



Patterns to include/exclude from the synchronization



Sync-13

Synchronized Projects

# Synchronized Project Properties

- Synchronized configurations can also be managed through the project properties
- Open the project properties by right-clicking on the project and selecting Properties
  - + Select Synchronize
- This is the same as using the Synchronize>Manage... menu

00	Properties for shallow
type filter text	Synchronize 🗘 🗸 🚽
<ul> <li>Resource Builders</li> <li>C/C++ Build</li> <li>C/C++ General</li> <li>Fortran Build Paths and Symbols</li> <li>Project References</li> <li>Run/Debug Settings</li> <li>Service Configurations</li> <li>Synchronize</li> <li>Task Repository</li> <li>Task Tags</li> <li>Validation</li> </ul>	Local Add trestles Remove Set Active CDT Build Configurations Default Configuration: Default_with_Linux_GCC ‡ Restore Defaults Apply
?	Cancel

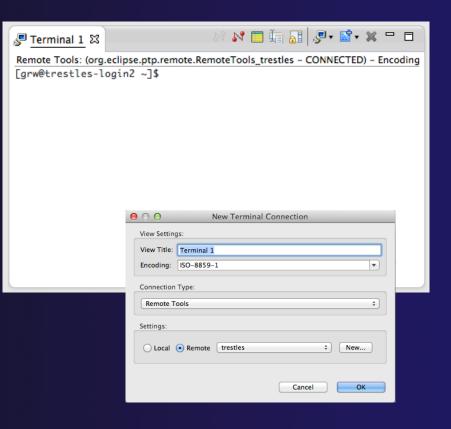
# Forcing a Resync

- If Auto-sync is set, the project should automatically resync with remote system when things change
- Sometimes you may need to do it explicitly
- Right click on project and select
   Synchronization>Sync Active
   Now
- Status area in lower right shows when Synchronization occurs

Build Configurations Make Targets Index	* * *		
Synchronize	•	Sync Active Now	
Validate Show in Remote Systems view F Convert to Fortran Project		Set Active Manage Sync All Now	•
Convert To		✓ Auto-Sync (Global)	
Run As	►	Auto-Sync Settings	•
Debug As	►	Filter	
Profile As	►		

# **Remote Terminal**

- There is a remote terminal that can be used to provide a shell from within Eclipse
- Select Window>Show
   View>Other...
- Choose Terminal from the Terminal folder
- In the Terminal view, click on the New Terminal Connection button
- Choose a previously configured connection from the dropdown, or create a new one



Remote C/C++ - hello/hello.c - Eclipse - /Users

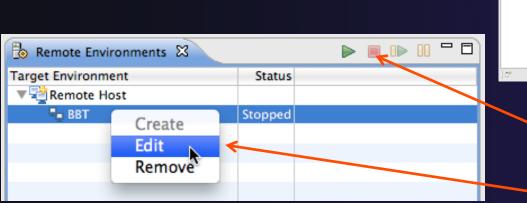
helloLocal.c

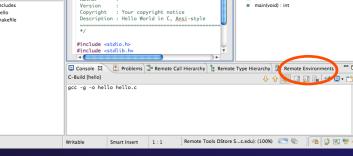
hello.c 🔀

Author

# Changing Remote Connection Information

If you need to change remote connection information (such as username or 🗎 🔝 🖆 - 😂 - 🗳 - 🍕 - 🚳 - 🖄 - 🔕 - 🔕 - 🖄 - 🍅 🔳 🕤 ] 🛃 + 🏹 + 🏷 🧇 - 🛛 password), use the **Remote** 🍐 Projec 🖾 🛛 📕 Remo 📄 🗖 🗖 🛙 🎼 hello ▶ .c hello.c **Environments** view ▶ 🔊 Include hello makefile





- Stop the remote connection first
- **Right-click and** select Edit
- Note: Remote Host may be stopped
  - + Any remote interaction starts it
  - No need to restart it explicitly

Parallel Runt... Premote C/C...

💱 🎼 😿 🐋 🔍 🐺 🏱

🗖 🗖 📴 Outline 🖾

stdio.h

stdlib.h



### Exercise

- Import an existing project into a synchronized project
  - Your login information and source directory will be provided by the tutorial instructor
- 2. Observe that the project files are copied to your workspace
- 3. Open a file in an editor, add a comment, and save the file
- 4. Observe that the file is synchronized when you save the file
  - Watch lower-right status area; confirm on host system



# **Optional Exercise**

### 1. Experiment with sync filters

- Create a filter to exclude files ending in ".o"
- Create an empty file ending in ".o" on the local system and verify it is not copied to remote machine after a sync
- Try creating a file on the remote system and verify that it is not copied

### 2. Create a new synchronize configuration

- Use the same host, different directory
- Synchronize the new configuration and verify that you have a second copy on the remote machine

# Building a Project

### ✦ Objective

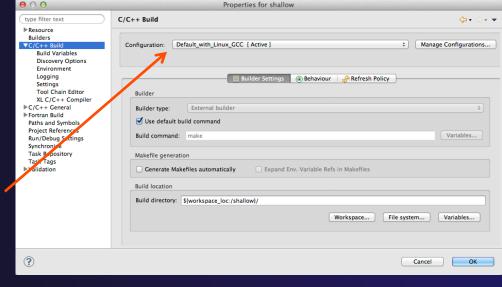
 Learn how to build an MPI program on a remote system

Contents

- + How to change build settings
- + How to start a build and view build output
- How to clean and rebuild a project
- How to create build targets

# **Build Configurations**

- A build configuration provides the necessary information to build the project
- The build configuration information is specified in the project properties
- Projects can have multiple build configurations, each configuration specifies a different set of options for a build
- Open the properties by rightclicking on the project name in the **Project Explorer** view and selecting **Properties** (bottom of the context menu list)



*Note: Fortran projects are a superset of C/C++ projects, so they have properties for both* 

# Build Properties (1)

#### + C/C++ Build

- Main properties page
- Configure the build command
- Default is "make" but this can be changed to anything
- Build Variables
  - Create/manage variables that can be used in other build configuration pages

#### Discovery Options

 Obsolete options page for discovering compiler settings (use C/C++ General>Preprocessor Include Paths instead)

#### Environment

Modify/add environment variables passed to build

#### + Logging

+ Enable/disable build logging



# Build Properties (2)

#### Settings

- Binary parser selection (used to display binaries in Project Explorer)
- Error parser selection (used to parse the output from compiler commands)
- Tool Chain settings (managed projects only)

#### + Tool Chain Editor

 Allows the tools in a particular tool chain to be modified

#### + XL C/C++ Compiler

Compiler settings for XL C/C++ compilers (if installed)



# Selecting Build Configuration

#### Multiple build configurations may be available

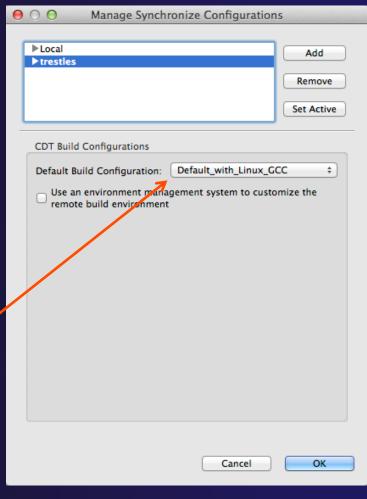
- + Synchronized projects will usually have a remote and a local build configuration
- + Build configurations for different architectures
- The active build configuration will be used when the build button is selected
- The Build Configurations project context menu can be used to change the active configuration
  - Right click on project, then select the build configuration from the Build Configurations > Set Active menu

Close Unrelated Projects				
Build Configurations		Set Active	>	✓ 1 Default_with_Linux_GCC
Make Targets	•	Manage		2 Default_with_MacOSX_GCC
Index Synchronize	•	Build All Clean All		
Validate Show in Remote Systems vi	iew	Build Selected		

Building a Project

# **Building Synchronized Projects**

- When the build button is selected, the "active" build configuration will be built on the remote system specified by the "active" synchronize configuration
- The build and synchronize configurations are independent
  - It is possible to change which build configuration is active, but make sure this makes sense on the remote system specified in the synchronize configuration
- A build configuration can be associated with a synchronize configuration, so that it is automatically selected when the synchronize configuration is changed



Build-5

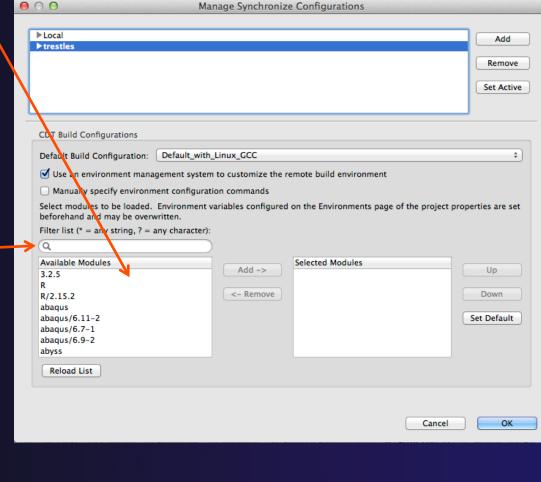
# Configuring the Build Environment

- If the remote system has an environment system (such as Modules) installed, a custom set of modules can be configured for building C/C++ projects
- In the Manage Synchronize / Configurations dialog, select the configuration you wish to change
- Check Use an environment
   management system to customize the remote build environment

0	O O Manage Synchronize Configurations				
	►Local ►tresties	Add Remove			
		Set Active			
	CDT Build Configurations         Default Build Configuration:         Output         Output<	\$			
ĺ	Available Modules     Selected Modules     Selected Modules				
	3.2.5 R R/2.15.2 abaqus/6.11-2 abaqus/6.7-1 abaqus/6.9-2 abyss Reload List	Up Down Set Default			
	Cancel	ОК			

# Build Environment (2)

- Select a module from the Available Modules list and click the Add-> button to add them to the Selected Modules list
- Use the <-Remove button to remove modules from the Selected Modules list
- Use the Filter list field to quickly find modules with a given name
- Use the Up and Down buttons to change the order of the Selected Modules
- Click Select Defaults to load only those modules that are present in a new login shell



# Build Environment (3)

### To build the project, Eclipse will

- + Open a new Bash login shell
- + Execute *module purge*
- + Execute module load for each selected module
- + Run *make*
- Module commands are displayed in the Console view during build
- Beware of modules that must be loaded in a particular order, or that contain common paths like /bin or /usr/bin

#### 📃 Console 🔀

#### CDT Build Console [shallow]

```
17:53:20 **** Build of configuration Default_remote for project shallow **** make all
```

```
**** Environment configuration script temporarily stored in /tmp/ptpscript_rhMesG ****
module purge >/dev/null 2>&1
module load cuda-4.0.17
module load cupti/4.0.17
module load clobus 5.0.4 m1
```

#### Building a Project

parallel tools platform

# Build Environment (4)

- For this tutorial, we want to use gcc and Open MPI
- Navigate to gnu/4.1.2 in Available Modules and select Add ->
- Navigate to openmpi/1.4.3 and select Add ->

fault Build Configuration: Default_with_Linux Use an environment management system to cu	_GCC istomize the remote l	ouild environment	<del>*</del>
Manually specify environment configuration co	mmands		
ect modules to be loaded. Environment variabl forehand and may be overwritten.	es configured on the	Environments page of the pro	ject properties are set
ter list (* = any string, ? = any character):			
•			
ailable Modules ichem/5.1.1 tave tave/3.6.2 enmpi cmpiexec	Add ->	Selected Modules gnu/4.1.2 openmpi/1.4.3	Up Down Set Default
cmpiexec/0.84 pi pi/4.1.3 pi/4.2.0			
Reload List			

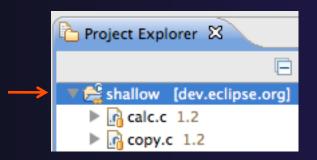
Building a Project

Build-9

parallel tools platform

# Starting the Build

Select the project in Project Explorer



 Click on the shammer button in toolbar to run a build using the active build configuration



Building a Project

parallel tools platform

#### parallel tools platform Viewing the Build Output Build output will be visible in console - -🚼 Problems 🧔 Tasks 📮 Console 🕱 🔲 Properties 🛛 🐁 Remote Environments 🏾 💭 Terminals CDT Build Console [shallow] 09:06:10 \*\*\*\* Build of configuration Default\_remote for project shallow \*\*\*\* make all Unloading compiler-dependent module openmpi/1.4.3 Note: mpicc appears to invoke gcc mpicc -g -c -o calc.o calc.c mpicc -g -c -o copy.o copy.c mpicc -g -c -o diag.o diag.c mpicc -g -c -o init.o init.c mpicc -q -c -o main.o main.c mpicc -g -c -o time.o time.c mpif90 -q -c -o tstep.o tstep.f90 mpicc -g -c -o worker.o worker.c mpicc -g -c -o dump.o dump.c

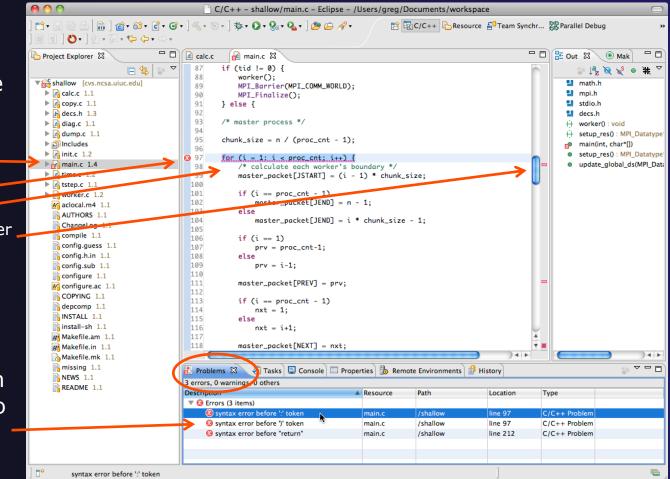
mpicc -q -o shallow calc.o copy.o diag.o init.o main.o time.o tstep.o worker.o dump.o -lm -lqfortran

09:06:15 Build Finished (took 4s.578ms)

Building a Project

Build-11

### **Build Problems**



 Build problems will be shown in a variety of ways

- Marker on file
- Marker on editor line ,
- + Line is highlighted
- Marker on overview ruler
- + Listed in the **Problems** view

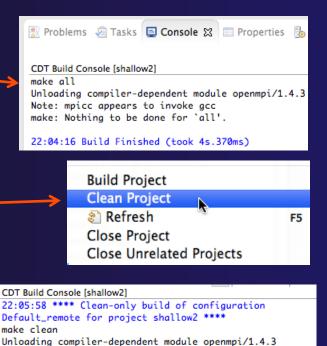
 Double-click on line in
 Problems view to go to location of error in the editor

Building a Project

Build-12

# Forcing a Rebuild

- If no changes have been made, make doesn't think a build is needed e.g. if you only change the Makefile
- In Project Explorer, right click on project and select Clean Project
- Build console will display results of clean
- Rebuild project by clicking on build button again



parallel tools platform

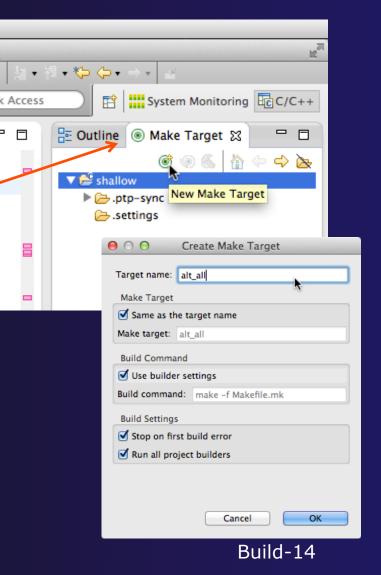
- Note: mpicc appears to invoke gcc
- rm -f shallow calc.o copy.o diag.o init.o main.o time.o
  tstep.o worker.o dump.o core

22:06:00 Build Finished (took 1s.535ms)

## Creating Make Targets

### ✤ By default

- The build button will run "make all"
- Cleaning a project will run "make clean"
- Sometimes, other build targets are required
- Open Make Target view
- Select project and click on New Make Target button
- Enter new target name
- Modify build command if desired
- New target will appear in view
- Double click on target to activate



### Exercise

- 1. Start with your 'shallow' project
- 2. Set the gnu/4.1.2 and openmpi/1.4.3 modules
- 3. Build the project
- 4. Edit a source file and introduce a compile error
  - In main.c, line 97, change ';' to ':'
  - Save, rebuild, and watch the Console view
  - Use the Problems view to locate the error
  - Locate the error in the source code by double clicking on the error in the **Problems** view
  - + Fix the error
- 5. Rebuild the project and verify there are no build errors



### **Optional Exercises**

- Open the Makefile in Eclipse. Note the line starting with "tags:" – this defines a make target named tags.
- 2. Open the Outline view while the Makefile is open. What icon is used to denote make targets in the Outline?
- 3. Right-click the **tags** entry in the Outline view. Add a Make Target for **tags**.
- 4. Open the Make Targets view, and build the tags target.
- 1. Rename Makefile to Makefile.mk
- 2. Attempt to build the project; it will fail
- 3. In the project properties (under the C/C++ Build category), change the build command to: make -f Makefile.mk
- 4. Build the project; it should succeed

# **Running an Application**

### ✦ Objective

Learn how to run an MPI program on a remote system

### + Contents

- Creating a run configuration
- Configuring the application run
- Monitoring the system and jobs
- Controlling jobs
- Obtaining job output

# Creating a Run Configuration

parallel tools platform

	Run Configurations
O ~ S <sub>■</sub> ~ Q ~ ] O ~ ] (no launch history)	Create, manage, and run configurations Create a configuration to launch a parallel application in Parallel Perspective
> <u>R</u> un As > Ru <u>n</u> Configurations Organize Fa <u>v</u> orites	Image: Sector of the selected type         Image: Sector
<ul> <li>Open the run configuration dialog Run&gt;Run</li> <li>Configurations</li> </ul>	- Edit or view an existing configuration by selecting it.  Configure launch perspective settings from the <u>Perspectives</u> preference page.
<ul> <li>Select Parallel Application</li> <li>Select the New button </li> </ul>	
Or, just double-click on <b>Parallel Application</b> to create a new one	Image: Second state     Filter matched 4 of 4 items       Image: Second state     Run       Close

*Note: We use "Launch Configuration" as a generic term to refer to either a "Run Configuration" or a "Debug Configuration", which is used for debugging.* 

Running an Application

Run-1

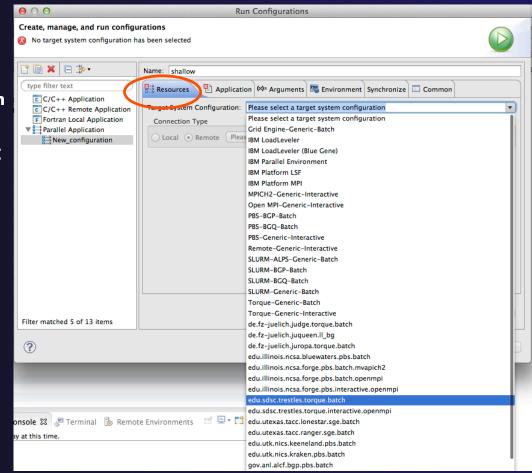
# Set Run Configuration Name

- Enter a name for this run configuration
  - + E.g. "shallow"
- This allows you to easily re-run the same application
- If the "shallow" project was selected when the dialog was opened, its name will be automatically entered

$\Theta \bigcirc \Theta$	Run Configurations					
Create, manage, and run configu	Create, manage, and run configurations					
😣 No target system configuration h	8 No target system configuration has been selected					
Y       Image: Second system         type filter text         C/C++ Application         C/C++ Remote Application         Fortran Local Application         Image: Parallel Application         Image: New_configuration	Name: shallow Resources Application Ø= Arguments Target System Configuration: Connection Type Local  Remote Please select a connection					
Filter matched 5 of 13 items						

# Configuring the Target System

- In Resources tab, select a Target System Configuration that corresponds to your target system
  - + Use edu.sdsc.trestles.torque.batch
- Target system configurations can be *generic* or can be specific to a particular system
- Use the specific configuration if available, or the generic configuration that most closely matches your system
- You can type text in the box to filter the configurations in the list



### **Configure the Connection**

- Choose a connection to use to communicate with the target system
- If no connection has been configured, click on the New button to create a new one
  - Fill in connection information, then click ok
- The new connection should appear in the dropdown list
- Select the connection you already have to trestles.sdsc.edu
- Select toggle if you don't want to see popup again

$\Theta \cap \Theta$	Ru	In Configurations			
Create, manage, and run configurations (Application): Application program not specified					
Yee       Yee         type filter text         C/C++ Application         C/C++ Remote Application         Fortran Local Application         Parallel Application         Hermitian         New_configuration	Name:       shallow         Image:       Application         Image:       Image:         Image:				
		(	Basic Settings Advanced Settings Import Script		
	Name Job Name:	Value ptp_job	Description The name assigned to the job by the qsub or qalte		
	Account: Queue:		Account to which to charge this job.		
	Number of nodes:	1	Number and/or type of nodes to be reserved for e [usage hint] number_nodes:ppn=N		
$\Theta \circ \circ$	Open Connec	tion			
Filter matcher	uration will run a command on t ??	the target system "tro	estles". Do you want		
⑦ Don't ask to run	i command again for this configu	uration	Close Run		
		No	Yes		

Running an Application

Run-4

### Resources Tab

- The content of the Resources tab will vary depending on the target system configuration selected
- This example shows the TORQUE configuration
- For TORQUE, you will normally need to select the Queue and the Number of nodes
- For parallel jobs, choose the MPI Command and the MPI Number of Processes

Name	Name: shallow							
B⊒ P	Exesources Application 🛛 Arguments 🖾 Environment Synchronize 🖾 Common							
Targ	Target System Configuration: edu.sdsc.trestles.torque.batch							
C	Connection Type							
0	O Local   Remote trestles    New							
		Basic Setting	as Advanced Settings Import Script					
		Basic Setting	Advanced Settings   Import Script					
	Name	Value	Description					
	Job Name:	ptp_job	The name assigned to the job by the qsub or qalter command.					
	Account:		Account to which to charge this job.					
	Queue:	÷	Designation of the queue to which to submit the job.					
~	Number of nodes:	1	Number and/or type of nodes to be reserved for exclusive use by the job. [usage hint] number_nodes:ppn=N					
	Total Memory Needed:		Maximum amount of memory used by all concurrent processes in the job.					
	Wallclock Time:	00:30:00	Maximum amount of real time during which the job can be in the running state.					
~	MPI Command:	÷	Which mpi command to use.					
~	MPI Number of Processes:	1	the '-np' value [usually equals Nodes*ppn]					
	Export Environment:		All variables in the qsub command's environment are to be exported to the batch job.					
	Modules to Load:	Configure	Modules that will be loaded inside the job script.					
	View Script	View Configuration Re	store Defaults					

### Resources Tab (2)

- ✤ For this tutorial, use the following values
  - + Queue: shared
  - + Number of nodes: 1:ppn=5
  - + MPI Command: mpirun
  - MPI Number of Processes: 5
  - Leave other fields alone

### Configure modules for running the application

- + Click on the *Modules to Load:* **Configure...** button
- Select the same modules used to build
  - + gnu/4.1.2
  - + openmpi/1.4.3

### Viewing the Job Script

- Some target configurations will provide a View Script button
- Click on this to view the job script that will be submitted to the job scheduler
- Batch scheduler configurations should also provide a means of importing a batch script

Account:			Account to which to charge this job.	
Queue:	shared	•	Designation of the queue to which to submit the job	
Number of nodes:	1:ppn=	5	Number and/or type of nodes to be reserved for exe [usage hint] number_nodes:ppn=N	
Total Memory Needed:			Maximum amount of memory used by all concurren	t
Wallclock Time:	00:30:0	0	Maximum amount of real time during which the job	•
MPI Command:	mpiri		Which moi command to use.	Script with
MPI Number of Processes:	5	Script with current v	alues	
Export Environment:	Viev	cp /home/tibbitts/s MYSCREXE=`basena COMMAND=mpirun if [ -n "\${COMMAND	on=5 0:30:00 _ARGS}" ] ; then restles/\$USER/\$PBS_JOBID shallow/shallow . ame /home/tibbitts/shallow/shallow` } ]; then MMAND} \${MPI_ARGS} -hostfile \${PBS_NODEFILE} \${MY	SCREXE} "

### **Application Tab**

- Select the Application tab
- Choose the Application program by clicking the Browse button and locating the executable on the remote machine
  - Use the same "shallow" executable
- Select Display output from all processes in a console view

00	Run Configurations			
Create, manage, and run configurations Create a configuration to launch a parallel application				
type filter text C/C++ Application Fortran Local Applicatik Java Applet Java Application	Name: shallow          Resource       Application       64= Arguments       Environment       Synchronize       Control         Project:       Shallow       Environment       Synchronize       Environment         Application       project:       Environment       Synchronize       Environment         Application       project:       Environment       Synchronize       Environment         Shallow       Environment       Environment       Synchronize       Environment         Application       project:       Environment       Synchronize       Environment	ommon Browse:		
► Launch Group ▼  ☐ Parallel Application ☐ shallow	Copy executable from local filesystem Path to local executable:	Browse		
	Display output from all processes in a console view	Browse		
Filter matched 7 of 7 items	Using Parallel Application Launcher - <u>Select other</u> Apply	Revert		
?	Close	Run		

# Arguments Tab (Optional)

- The Arguments tab lets you supply command-line arguments to the application
- You can also change the default working directory when the application executes

00	Run Configurations			
Create, manage, and run configurations Create a configuration to launch a parallel application				
Ype filter text         E         C/C++ Application         Fortran Local Application         Java Applet         Java Application         ▲ Launch Group         Parallel Application         Shallow	Name: shallow          Resources       Application       Arguments         Program arguments       Working directory         ✓       Use default working directory         Directory       Browse			
Filter matched 7 of 7 items	Using Parallel Application Launcher - <u>Select other</u> Apply Revert			
?	Close Run			

# Environment Tab (Optional)

- The Environment tab lets you set environment variables that are passed to the job submission command
- This is independent of the Environment Management (module/softenv) support described in a separate module

00	Run Configurations	
Create, manage, and run con Create a configuration to launci	-	
Y     Y     Y       Type filter text       C/C++ Application	Name: shallow	Common
	Variable Value	New Select Edit Remove
Filter matched 7 of 7 items	Append environment to native environment     Replace native environment with specified environment Using Parallel Application Launcher - <u>Select other</u> Apply	Revert
?	Close	Run

Run-11

# Synchronize Tab (Optional)

- The Synchronize tab lets you specify upload/ download rules that are execute prior to, and after the job execution
- Click on the New upload/download rule buttons to define rules
- The rule defines which file will be uploaded/ downloaded and where it will be put
- Can be used in conjunction with program arguments to supply input data to the application

00	Run Co	onfigurations			
Create, manage, and run configurations Add synchronization rules to upload files before the launch or to download files after the application terminates.					
Image: Second system         Type filter text         C C/C++ Application         E Eclipse Application         Fortran Local Application         Java Applet         Java Application         JujUnit         JujUnit         Vaunch Group         OSGi Framework         Parallel Application         Image: Shallow-torque	Synchronize rules:	Arguments       Image: Environment Synchronize       Common Synchronize         Dere application starts.       Download rules are executed after ap         Image: Specify the remote directory and a list of files that shall be uploaded         Remote directory:         Image: Specify the remote directory and a list of files that shall be uploaded         Remote directory:         Image: Specify the remote directory in launch configuration         Remote directory:         Selected file(s):	plication finishes		
Filter matched 11 of 11 items	Using Parallel Application Laun		nove files: Remove selected		
?		Options for all selected file(s):         Readonly       Executable         Download back if changed       Preserve time attributes         If file already exists:       Overwrite       \$			
		(?) Cancel	ОК		

# Common Tab (Optional)

- The Common tab is available for most launch configuration types (not just Parallel Application)
- Allows the launch configuration to be exported to an external file
- Can add the launch configuration to the favorites menu, which is available on the main Eclipse toolbar
- Select **Run** to launch the job

00	Run Configurations	
Create, manage, and run confi Create a configuration to launch a	•	
Image: Second system         type filter text         C C/C++ Application         E Clipse Application         Fortran Local Application         Java Applet         Java Applet         Java Application         JUJunit         JUJUnit         OSGI Framework         Parallel Application         Image: Shallow-torque	Name:       shallow-torque         Image: Resources       Image: Application       Arguments       Image: Solution         Save as       Image: Local file       Image: Solution       Image: Solution       Image: Solution         Display in favorites menu       Image: Solution       Image: Soluti	Encoding
Filter matched 11 of 11 items		
?		Close Run

### Run

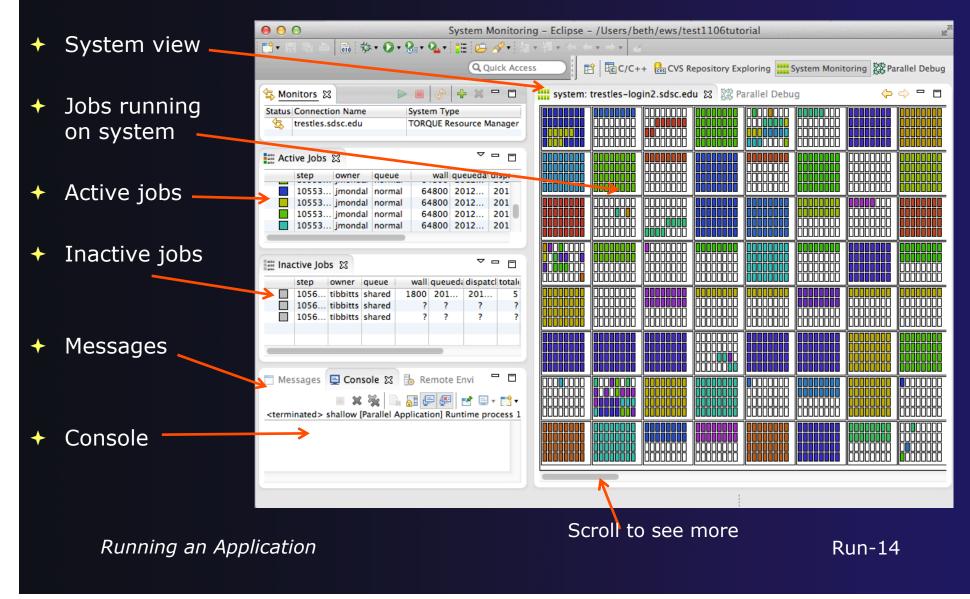
 Select **Run** to launch the job
 You may be asked to switch to the System Monitoring Perspective



Select Remember my decision so you won't be asked again

Select Yes to switch and launch the job

# System Monitoring Perspective



### Moving views

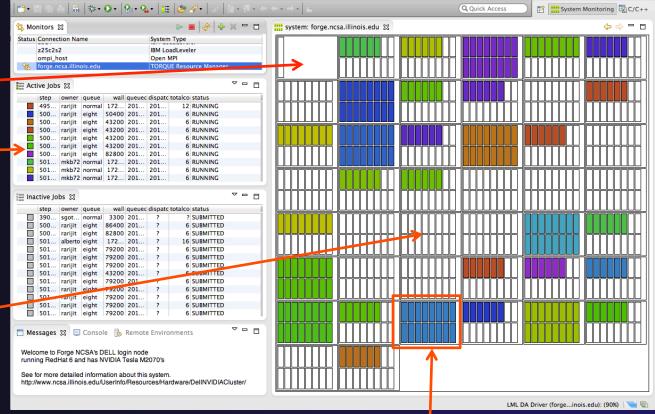
- The System Monitoring Perspective overlaps the Active Jobs and Inactive Jobs views
- To split them apart and see both at once, drag the tab for the **Inactive Jobs** view to the lower half of its area, and let go of mouse

ett Acti	ive Job	S and a	nactive	Jobs	x				3
	step	owner	queue	wall	queue	dispat	totalcc	status	
	510	llev	nor	129	20	?	16	SUBMITTED	
	510	llev	nor	. 29	20	?	16	SUBMITTED	
	510	llev	nor	129	20	?	16	SUBMITTED	
	510	llev	nor	129	20	?	16	SUBMITTED	۳.
	510	llev	nor	12	20	?	16	SUBMITTED	
	510	llev	nor	129	20	?	16	SUBMITTED	
	510	llev	nor	129.	20	1	16	SUBMITTED	
	510	llev	nor	129.	20	?	16	SUBMITTED	
	510	llev	nor	129	20	?	16	SUBMITTED	
	510	llev	nor	129	20	?	16	SUBMITTED	
	510	llev	nor	129	20	?	16	SUBMITTED	
	510	llev	nor	129	20	?	16	SUBMITTED	
	510	llev	nor	129	20	?	16	SUBMITTED	
	510	llev	nor	129	20	?	16	SUBMITTED	

Ac	tive Joł	os 🖾							
	step	owner	queue	wall	queue	dispat	totalcc	status	
	509	alb	eight	172	20	20	24	RUNNING	
	509	alb	eight	172	20	20	24	RUNNING	
	509	rdel	nor	172	20	20	4	RUNNING	
	509	rdel	nor	172	20	20	4	RUNNING	
	1								
-									
iiii Ina	ictive J	obs 🛛	)					⊽ □	
	ctive J			wal	queue	dispat	totalc	⊽ ⊡	
		owner	queue	-		dispat ?	-	status SUBMITTE	
	step 510	owner	queue nor	129	20	?	16		-
	step 510	owner llev	nor	129 129	20 20	?	16	SUBMITTE	D
	step 510	owner Ilev Ilev	nor nor	129 129 129	20 20 20	? ? ?	16 16 16	SUBMITTE SUBMITTE	D
	step 510 510 510 510	owner Ilev Ilev Ilev	nor nor nor nor	129 129 129 129	20 20 20 20	? ? ?	16 16 16	SUBMITTE SUBMITTE SUBMITTE	D
	step 510 510 510 510	owner llev llev llev llev	nor nor nor nor	129 129 129 129	20 20 20 20	? ? ? ? ?	16 16 16	SUBMITTE SUBMITTE SUBMITTE SUBMITTE	D D D D

### System Monitoring

- System view, with abstraction of system configuration
- Hold mouse button down on a job in
   Active Jobs view to see where it is running in System view
- Hover over node in System view to see job running on node in Active Jobs view



One node with 16 cores

Run-16

## Job Monitoring

4084 4086 4086

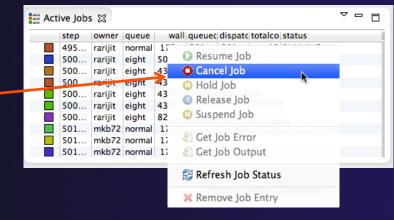
- Job initially appears in Inactive Jobs view
- Moves to the Active Jobs
   view when execution begings
- Returns to **Inactive Jobs** view on completion
- Status refreshes automatically every 60 sec
- Can force refresh with menu

00	🗋 System Monit	oring - shallow/Make	efile.mk – Eclipse – /Users/beth/ews/test10
💁 🖬 🗟 📥 🖬 🖥 🗫 💽	• 🏊 • ] 📰 ] 🗁 🛷 • ]	£ • ₽ • \$ \$ \$ \$ \$	• EY System Mo
Resource Managers 🕱			🗖 🗖 🏭 system: forge.ncsa.illinois.edu 🔀
PBS-Generic-Batch (LML_JAXE	3)		
Active Jobs 📰 Inactive Jobs 🕱	3		
step owner queue	wall queueda dispat	totalcore: status	
3626.fsched gopal debug		? SUBMITTED	
3627.fsched gopal debug		? SUBMITTED ? SUBMITTED	
		. 506001120	
Active Jobs	Inactive Jobs 🕱		
step	owner queue	wall queueda dispat A	
	hed gopal debug hed gopal debug	600 2011 ? 600 2011 ?	? SUBMITTED ? SUBMITTED
	hed tibbitts debug	77 7	
	actual actua		🥄 🔘 Resume Job
			Cancel Job
			Hold Job
			Release Job
			O Suspend Job
			U Suspena job
			🔊 Get Job Error
			🔊 Get Job Output
			Refresh Job Status
			🗙 Remove Job Entry
			Dun-17

Run-17

## Controlling Jobs

- Right click on a job to open context menu
- Actions will be enabled IFF
  - The job belongs to you
  - The action is available on the target system
  - The job is in the correct state for the action
- When job has COMPLETED, it will remain in the **Inactive** Jobs view

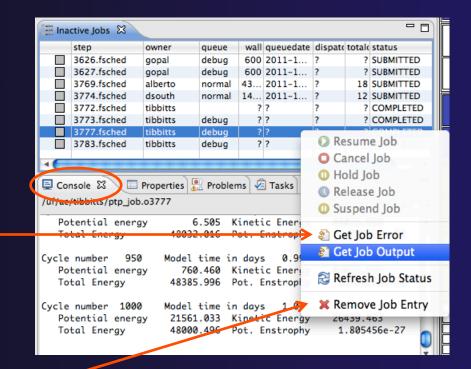


III Inad	ctive Jol	os 🛛							~	
	step	owner	queue	wall	queuec	dispate	totalco	status		
	501	rarijit	eight	79200	201	?	6	SUBMITTED		
	501	rarijit	eight	79200	201	?	6	SUBMITTED		
	501	rarijit	eight	79200	201	?	6	SUBMITTED		
	501	rarijit	eight	79200	201	?	6	SUBMITTED		
	502	nvellor	normal	86400	201	?	6	SUBMITTED		
	503	boxu	normal	28800	201	?	64	SUBMITTED		
	503	boxu	normal	18000	201	?	64	SUBMITTED		
	503	boxu	normal	18000	201	?	64	SUBMITTED		
	503	boxu	normal	28800	201	?	64	SUBMITTED		
	504	alberto	eight	172	201	?	24	SUBMITTED		
	504	alberto	eight	172	201	?	24	SUBMITTED		
	504	inca	normal	300	201	?	4	SUBMITTED		
	501	grw		?	?	?	?	COMPLETED		

## **Obtaining Job Output**

### After status changes to COMPLETED, the output is available

- Right-click on the job
- Select Get Job Output to display output sent to standard output
- Select Get Job Error to retrieve output sent to standard error —
- Output/Error info shows in Console View
- Jobs can be removed by selecting **Remove Job Entry**



## Add a Monitor

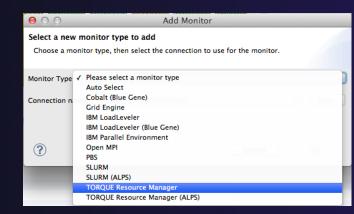
### You can monitor other systems too

In Monitors view, select the '+' button to

add a monitor

🔄 Mor	nitors 🕱 🛛 🕨	• • • • •
Status	Connection Name	System Type
	gordon	TORQUE Resource Manager
	trestles.sdsc.edu	TORQUE Resource Manager

Choose monitor type and connection; create a new connection if necessary



Double click new monitor to start

Running an Application

Run-20

### Exercise

- 1. Start with your 'shallow' project
- 2. Create a run configuration
- 3. Complete the Resources tab
- 4. Select the executable in the Application tab
- 5. Submit the job
- Check the job is visible in the Inactive Jobs view, moves to the Active Jobs view when it starts running (although it may be too quick to show up there), then moves back to the Inactive Jobs view when completed
- 7. View the job output
- 8. Remove the job from the Inactive Jobs view

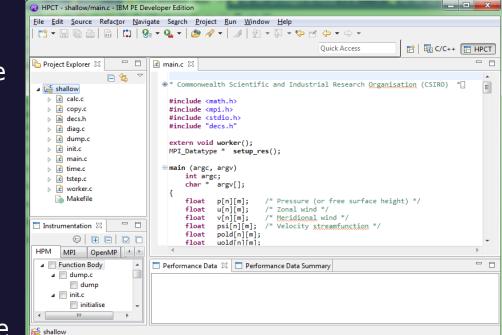


Update May 2013

## HPC Toolkit

### Objective

- Learn how to use the HPC Toolkit to analyze the performance of your applications
- Contents
  - + Introduction
  - Application CPU
     Profiling using Xprof
  - Profiling using hardware performance counters
  - MPI profiling and tracing



## What is HPC Toolkit?

### Set of performance tools integrated with Eclipse and PTP

- + Hardware performance counter profiling
- MPI profiling and tracing
- OpenMP profiling
- I/O profiling and tracing
- Application CPU profiling
- Binary instrumentation tools

## Hardware Performance Counters

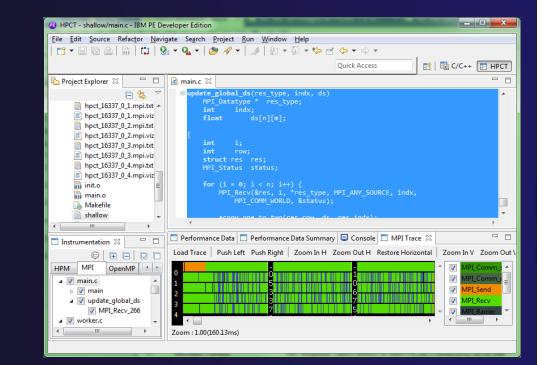
- Helps identify problem code areas
  - Excessive CPU resource usage
- Collects hardware performance counter event counts
- Reports hardware performance counters for functions, blocks
- View multiple tasks
- ✦ Sort/filter data

HPCT - shallow/main.c - IBM PE De	veloper Edition	
<u>File Edit Source Refactor Navig</u>	gate Se <u>a</u> rch <u>P</u> roject <u>R</u> un <u>W</u> indow <u>H</u> elp	
📑 🗕 🗟 👜   🛄   😢	╘ <b>╶ Q<sub>6</sub> र   29 // र   3</b>   🛃 🐇 <b>र ¦i - ∜</b> ⊃ 🖻 (⊃ <b>र</b> ⇒) र	
	Quick Access	📄 🛛 📅 🛛 🛱 C/C++ 🔳 HPCT
	i main.c ⊠	
🖻 🔁 🎽	<pre> wpdate_global_ds(res_type, indx, ds) MPI Datatype * res type; </pre>	<b>^</b>
alc.o 🔺	int indx;	
copy.o	<pre>float ds[n][m];</pre>	
diag.o	e de la companya de l	
dump.o hpct_16031_0_0.hpm.sł	i int i;	
hpct_16031_0_0.hpm.sr	int row;	
hpct_16031_0_2.hpm.sł	struct res res;	
■ hpct_16031_0_Linpmist =	MPI_Status status;	
hpct_16031_0_4.hpm.sł	for (i = 0; i < n; i++) {	
init.o	MPI_Recv(&res, 1, *res_type, MPI_ANY_SOUR	CE, indx,
🗟 main.o	<pre>MPI_COMM_WORLD, &amp;status);</pre>	
🚡 Makefile 👻	econy one to two/ces cow ds pes indx).	·
4 III >		F
🗖 Instrumentation 🛛 🗖 🗖	Performance Data 🗖 Performance Data Summary 🛛 📮 Conso	le 🕀 🕀 🗖
	Data for rank 0, Aggregation for tasks: 0 1 2 3 4	
HPM MPI OpenMP	Label User time	Execution time
Function Body	initialise	0.001
a 🔽 dump.c	⊿ main.c	E
<b></b> dump	update_global_ds	0.627
⊿ 📝 init.c	setup_res	0.000
initialise ←	⊿ diaα.c	
		۴
	Writable Smart Insert 273 : 1	

## **MPI Profiling and Tracing**

### Profiles MPI calls

- Time spent
- Number of calls
- Message sizes
- Traces MPI calls
  - Traces individual MPI calls
  - Identifies
     communication
     patterns
  - Time spent/message size per MPI call



## **OpenMP** Profiling

### Profiles OpenMP programs

- Time spent in parallel region
- Time waiting for barriers
- Number of invocations of parallel region
- Identify load imbalances across threads

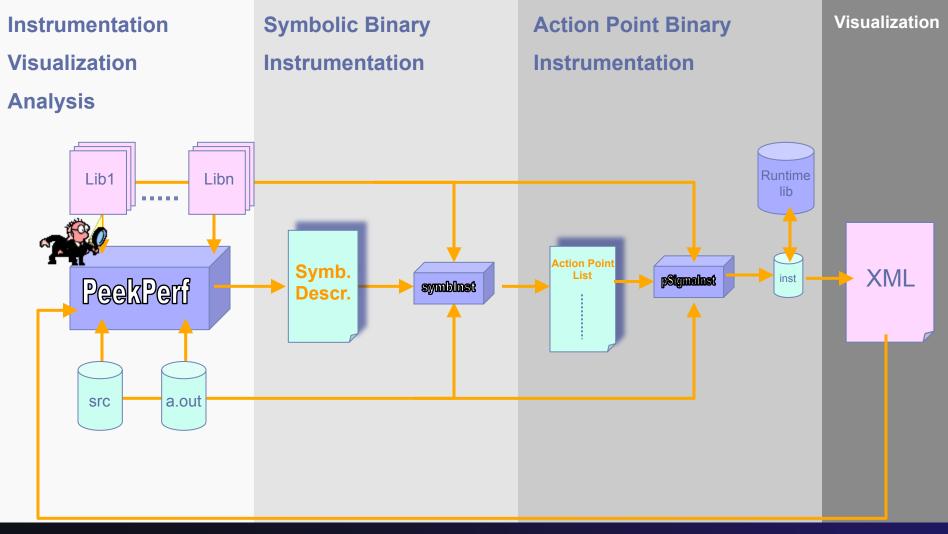
😢 HPCT - homb/src/homb.c - IBM PE Developer Edition							
<u>File Edit S</u> ource Refac <u>t</u> or <u>N</u> avigate Se <u>a</u> rch <u>P</u> roject <u>R</u> un <u>W</u> indow <u>H</u> elp							
C → 🔄 🕲 - 🗎   🛄   🚱 → 💁 →   🥭 🛷 →   🥒   ½ → 🖗 → 🗢 → → →							
		Quick Access					
Project Explorer 🛛 🗖 🗖	li homb.c ⊠		- 8				
E ⊊ ▽	⊕ This is the source for HC ⊖ /* Copyright 2009 <u>Maxwell</u>		Benchmark, a <u>Laplace</u> Solver.				
<ul> <li>▷ c→ jobs</li> <li>△ c→ jobs</li> <li>△ c→ src</li> <li>▷ c→ utils</li> <li>□ homb.ex</li> <li>□ homb.ex</li> <li>□ homb.ex</li> <li>□ homb.ex13850 0 0.00mp.tx</li> </ul>	it under the terms of t the Free Software Found (at your option) any la	you can redistribute it an the GNU General Public Lice dation, either version 3 of	nse as published by the License, or				
<pre>hpt17850_0omp.vi hpt17850_0_1.omp.vi hpt17850_0_1.omp.vi hpt17850_0_1.omp.vi hpt17850_0_1.omp.vi hpt1</pre>	but WITHOUT ANY WARRANT	TY; without even the implie NESS FOR A PARTICULAR PURPO	d warranty of				
	Performance Data 🔲 Performance	e Data Summary 🕱 📃 Console	🗖 MPI Trace 🛛 🕀 🗖				
	Data for rank 0, Aggregation for tasks	:01					
HPM MPI OpenMP	Label	Count	Excl. Time				
<ul> <li>Ø homb.c</li> <li>Ø workSSOLS\$4\$SOL\$\$5</li> <li>Ø cpuLocationOutput\$\$OI</li> <li>Ø extraCalculations\$\$OL\$\$</li> <li>Ø work\$\$OL\$\$4</li> </ul>	▲ homb.c pregion_491	20	4.009450				
	•		•				
🔂 homb							

## I/O Profiling and Tracing

- Profiles I/O system calls
  - + Time spent
  - Number of calls
  - + Bytes per I/O
- Traces I/O calls
  - Traces individual I/O system calls
  - Statistics about I/O

e HPCT - mio/mio_c1.c - IBM PE Dev	eloper Edition			
<u>File Edit Source Refactor Navi</u>				
📬 🗕 🔚 🖷 👜   🛄   😫	} <b>: ▼ Q. ▼</b>   🍅 🖋 ▼   _	🥖 🖢 🕶 🖓 🕶 🏷 📑 🔶	• ⇔ •	
		Quid	k Access	C/C++ HPCT
陷 Project Explorer 🛛 📃 🗖	i mio_c1.c ⊠			
E Shamb > C mio > C shallow	<pre>#include <sys ty<br="">#include <sys sta<br="">#include <fcntl.h #include <fcntl.h #include <unistd. #include <unistd. #include</unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </unistd. </fcntl.h </fcntl.h </sys></sys></pre>	t.h> > h> > 64(char *fn);		for tests using 🔎
< <u> </u>	*			4
🗖 Instrumentation 🛛 🗖 🗖	Performance Data 🗖 P	erformance Data Summary 🛛	📮 Console 📃 MPI Trace	
	Data for rank 0, Aggregatic	on for tasks: 0		
MPI OpenMP MIO + +	Label	EVENT COUNT	CUMULATI	/E TIME[SECS]
✓ close_72 ▲	4 X			
▲ process_file	read	3	0.00	E
open_39	close	1	0.00	
□ close_51 =	fcntl	1	0.00	
⊿ 📝 read_data	open	1	0.00	<b>T</b>
✓ read_80 +		III		•
🚅 mio				

# Binary Instrumentation



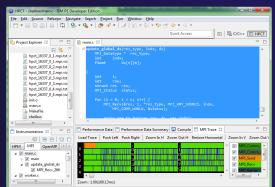
HPC Toolkit

HPCT-6

**IBM HPC Toolkit** 

### Using HPC Toolkit Possible workflow

- Compile in preparation for profiling (-pg option)
- Run to generate gmon.out files
- Run Xprof to determine 'hot' functions in application
- Instrument 'hot' functions in application for performance data gathering
  - + Hardware Performance Counters, MPI, OpenMP, I/O
- Run the instrumented application
- Analyze application performance with HPC Toolkit tools
- Correct performance problems
   ... and repeat

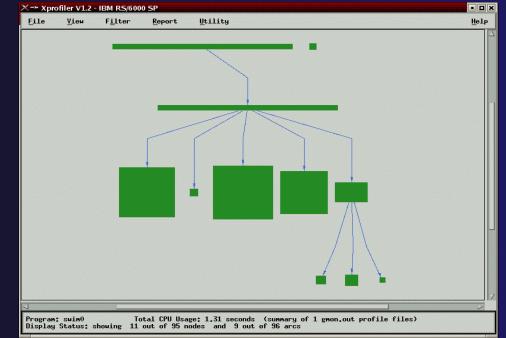




IBM HPC Toolkit

## Application CPU Profiling

- Profiles entire application
  - Shows time spent in each function
  - Easily identify highest CPU usage
  - Shows proportion of time in caller and callee
  - Additional views and reports for more detail





## Compiling the Application

HPCT-9

## **Compilation Requirements**

- Compile flags for Hardware performance counters, MPI, OpenMP and I/O profiling
  - ✦ AIX: -g
  - Linux: --emit-stub-syms -WI,--hash-style=sysv -g
- Compile flags for CPU profiling with Xprof
  - AIX and Linux: Application must be compiled and linked with -g and -pg flags



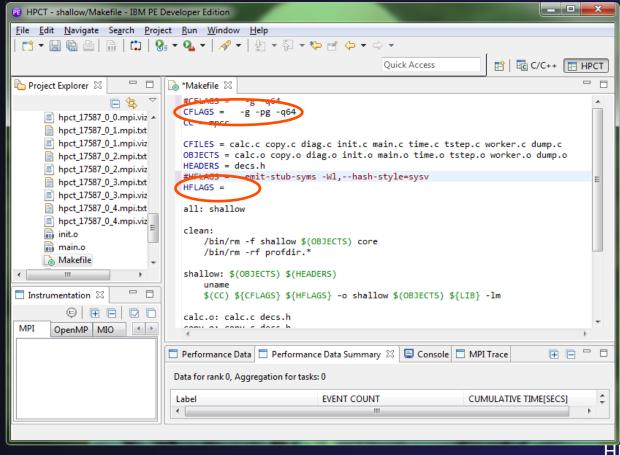
## Xprof (CPU Profiling)

## **Xprof and Remote Systems**

- \* Xprof not yet integrated with Eclipse
- Useful tool for getting overview of application performance
- Xprof must be run on remote AIX or Linux system
- Application can be run on remote system
- Application can also be run using PTP
- Tutorial fragment explains how to run on remote system

## Set Up Makefile (Xprof)

## Makefile should look like following view (shows AIX) Should have all and clean targets

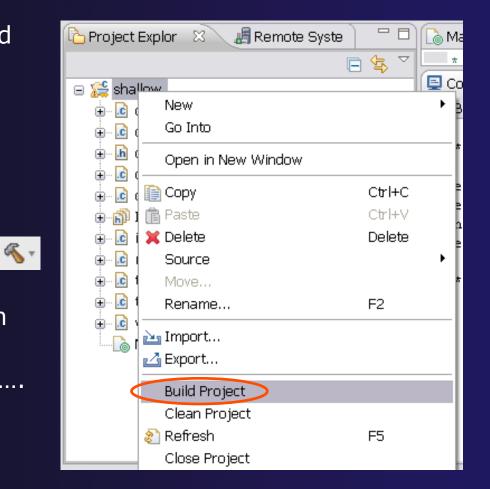


HPC Toolkit

**HPCT-13** 

## Build the Application

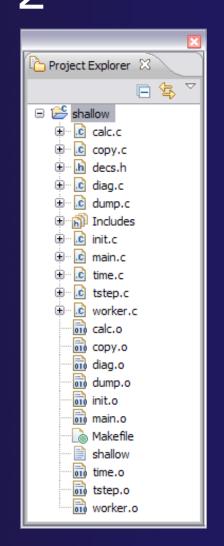
- Make source code changes and save
- Right click project name in
   Project Explorer view
- Click Build Project in popup menu
  - Or select project and use hammer icon in toolbar
- Force build by clicking Clean
   Project then Build Project in popup menu
  - + Or Menu: Project ► Clean....



# Build the Application 2

- Project Explorer updates to show new files
- Console view shows build log

Donsole X	🕂 🕂 🔄 🔚 🔐 🖓 🚽 🖓	•
CDT Build Console [shallow]		
mpcc -g -pg -c -o calc.o calc.c		$\sim$
mpcc -g -pg -c -o copy.o copy.c		
mpcc -g -pg -c -o diag.o diag.c		
mpcc -g -pg -c -o init.o init.c		
mpcc -g -pg -c -o main.o main.c		
mpcc -g -pg -c -o time.o time.c		
mpcc -g -pg -c -o tstep.o tstep.c		
mpcc -g -pg -c -o worker.o worker.c		
mpcc -g -pg -c -o dump.o dump.c		
<pre>mpcc -g -pg -o shallow calc.o copy.o diag.o init.o main.o time.o</pre>	o tstep.o worker.o dump.o -lm	



**IBM HPC Toolkit** 

HPC Toolkit

HPCT-15

## Log on Login Node

- Open xterm on local machine
- ssh w/X11 tunneling to login node (2 hops)
- ssh tunneling for X11 must be enabled (by admins)

X ~	
Main Options VT Options VT Fonts	
desktop:/u/wootton> ssh -Y 192.168.206.12 192.169.206.12:/u/wootton> ssh -Y 172.16.0.3 172.16.0.3:/u/wootton>	

## Set Up and Run Application

Set PE environment variables

Run application

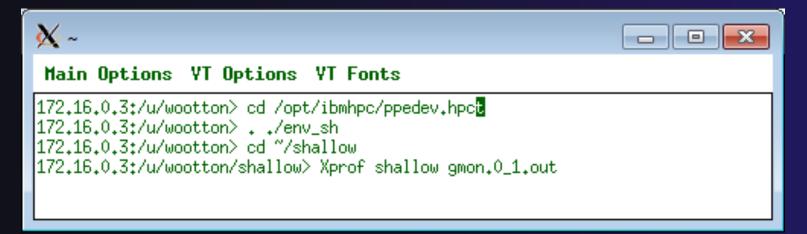
×~	
Main Options VT Options VI	[ Fonts
export MP_PROCS=5 export MP_TASKS_PER_NODE=5 export MP_EUILIB=us export MP_RESD=yes export MP_RMPOOL=1 export MP_EUIDEVICE=sn_single export MP_DEVTYPE=hfi \$ cd ~/shallow \$ ./shallow	

## Display results using Xprof

Set up HPC Toolkit environment (env.sh)

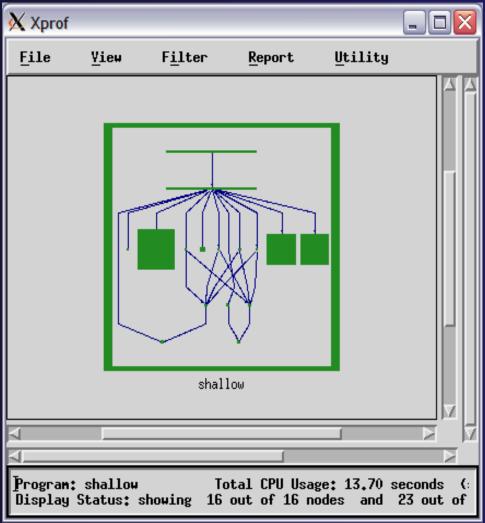
Invoke Xprof with executable and gmon.out files

Can specify multiple gmon.out files



## **Xprof Initial View**

- Large green box for executable and each shared library (AIX)
- Nodes represent functions, lines represent caller/callee relationship
- Size of block representative of time in function
  - Width: Function & all of its callees
  - + Height: Function only

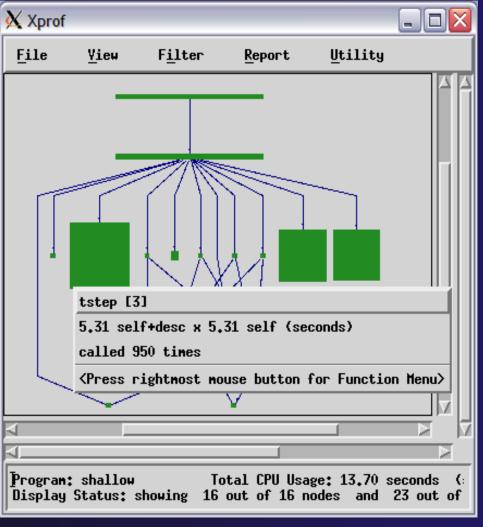


HPC Toolkit

HPCT-19

## **Expand Application Tree**

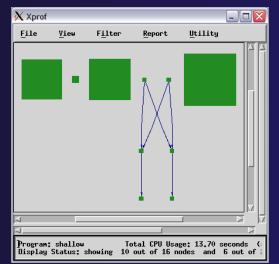
- Right click on outer green box
- Click Remove Cluster
   Box in popup menu
- Left click on nodes (boxes) to see function detail
- Left click on arcs to see caller/callee details
- Right click node or arc for additional actions
- Use View menu to zoom
- Use scrollbars to scroll



## Filter Call Graph

- Click on Filter menu
- Click on Filter by CPU
   Time
- Drag slider to desired number of functions
- Lowest time functions filtered out
- Additional filters
  - Call counts
  - Function name
- Click Show Entire Call
   Tree to restore

🗙 Filter By CPU Time Dialog 🛛 🛛 🔀
Number Of Functions To Be Displayed:
10
Slider Value: 10
♦ show functions consuming the most CPU time
$\checkmark$ show functions consuming the least CPU time
OK Apply Cancel



HPC Toolkit

HPCT-21

## Call Graph Profile Report

- Click on **Report** menu
- Click on Call Graph
   Profile
- Report shows
  - Time spent in function and descendants
  - Number of times a function was called

			,	,		_
🔆 Call (	Graph Pro	ofile				X
<u>F</u> ile						
index	%time	self de	escendents	called/total called+self called/total	parents name index children	
[1]	100.0	$\begin{array}{c} 0.00\\ 0.00\\ 5.31\\ 4.10\\ 4.00\\ 0.29\\ 0.00\\$	$\begin{array}{c} 13.70\\ 13.70\\ 0.00\\ 0.00\\ 0.00\\ 0.00\\ 0.00\\ 0.00\\ 0.00\\ 0.00\\ 0.00\\ 0.00\\ 0.00\\ 0.00\\ 0.00\\ 0.00\\ 0.00\end{array}$	1/1 1 950/950 950/950 950/950 19/19 3584/13084 950/950 950/950 950/950 950/950 5/5 1/1	<pre>main [2] worker [1] tstep [3] timetend [4] calcuvzh [5] diag [6] acopy_one_to_two [7] calc_load [11] calc_unload [12] time_load [13] time_unload [14] send_updated_ds [15] setup_res [16]</pre>	-
[2]	100.0	0.00 0.00	13.70 13.70	1/1	<spontaneous> main [2] worker [1]</spontaneous>	
[3]	38,8	5.31 5.31	0.00 0.00	950/950 950	worker [1] tstep [3]	
[4]	29.9	4.10 4.10	0.00 0.00	950/950 950	worker [1] timetend [4]	
[5]	29.2	4.00 4.00	0.00 0.00	950/950 950	worker [1] calcuvzh [5]	
M						
	Engine:	(regular	expression	ns supported)		
Ĭ						



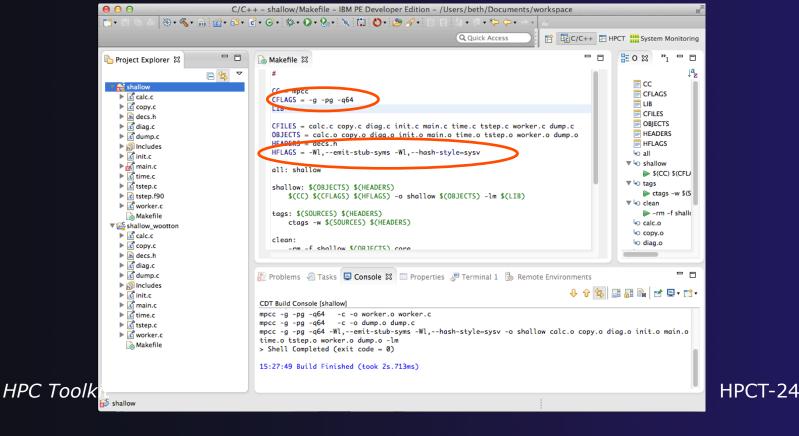
## Hardware Performance Counter Profiling

HPC Toolkit

HPCT-23

## **Rebuild Application**

- Update Makefile to use correct compile/link flags (shows Linux)
  - + CFLAGS = -g -pg -q64
  - + HFLAGS = -WI,--emit-stub-syms -WI,--hash-style=sysv
- Rebuild application using Project->Clean Project then Project->Build Project



## Set up Profile Configuration

- Select Run in main menu
- Select Profile Configurations in menu
- + Assuming you already have a configuration for 'shallow' ...
- Select existing run configuration from Parallel Application tab
- Make changes on following pages as needed

Profile Configurations						
<b>Create, manage, and run configurations</b> Build C, C++ or Fortran applications with performance analysis tools. Launch parallel programs from within Eclipse via the PTP.						
	Configure launch settings from this dialog: Press the 'New' button to create a configuration of the selected type. Press the 'Duplicate' button to copy the selected configuration. Press the 'Delete' button to remove the selected configuration. Filter' button to configure filtering options. Press the 'Delete' button to configure filtering options. Configure launch perspective settings from the 'Perspectives' preference page.					
Filter matched 3 of 3 items						
?	Profile	Close				

## Set up Profile Configuration 2

Launch config information from previous run

00	Profile Conf	figurations		
Create, manage, and run configuration () [Performance Analysis]: No workflow sele				٩
Yee       Image: Second	Use LoadLeveler:	ronment com  System Nodes Performance 1  /u/tibbitts/hostfile_linux  5	ance Analysis Comm	* New
Filter matched 4 of 4 items			Ap	ply Revert
?			C	lose Profile

## Set up Profile Configuration 3

Switch to Performance Analysis tab

If not already set, Select Tool: HPC Toolkit

Wait while the executable is analyzed "Analyzing Binary"

0 0	Profile Configurations	Circles and stores
Create, manage, and run configu No workflow selected.	urations	١
Image: Second system         type filter text         C/C++ Application         Launch Group         Image: Second system         Image: Second system         Image: Shallow	Select tool:   Please select a workflow  IBM HPC Toolkit  PerfSuite  Build the instrumented executable but do not launch it  Select existing performance data to analyze with the selected tool	"2
Filter matched 4 of 4 items		
?	Close	Profile

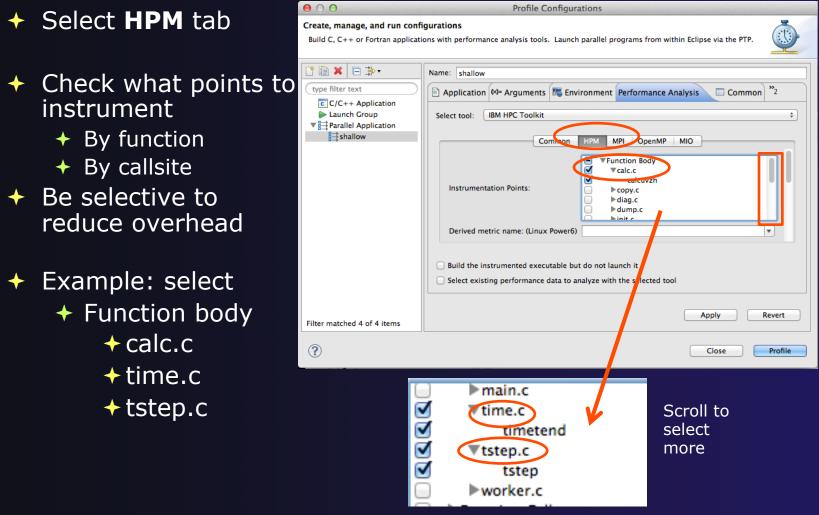
## Set up Profile Configuration 4

Select the Common tab

HPC 7

- Check the Generate unique filenames checkbox
  - Adds job PID to performance output filenames

## Profile Configuration: HPM 1



HPC Toolkit

HPCT-29

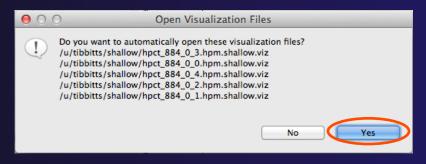
## Profile Configuration: HPM 2

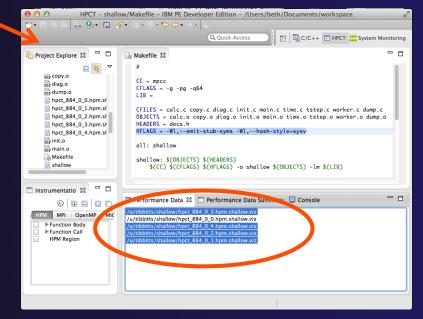
- Select Derived Metric Name (e.g. MIPS)
- Select Generate visualization files
- Select Profile button to run the profile analysis
- Program is instrumented then executed

	Profile Configurations
Create, manage, and run confi Build C, C++ or Fortran applicati	gurations ons with performance analysis tools. Launch parallel programs from within Eclipse via the PTP.
Image: Second secon	Name:       shallow         Application       Marguments       Environment       Performance Analysis       Common       "2         Select tool:       IBM HPC Toolkit       *       *       *       *         Common       MPI       OpenMP       MIO       *       *       *         Derived metric name:       (Linux Power6)       MIPS       *       *       *         Hardware counter group:       Aggregation plugin name:       *       *       *       *         Aggregation plugin name:       *       *       *       *       *       *         MPI task to display results:       *       *       *       *       *       *         FLOPS weighting factor:       *       *       *       *       *       *       *         Build the instrumented executable but do not launch it       *
Filter matched 4 of 4 items	Apply Revert
?	Close Profile

### View HPM Performance Data

- Popup appears after application runs, click
   Yes to open viz files
- HPCT Perspective with
   Performance Data view
   opens
- Make sure performance data files are selected
  - Can select files with click, shift-click, ctrl-click
  - Deselect task 0 to get compute data info



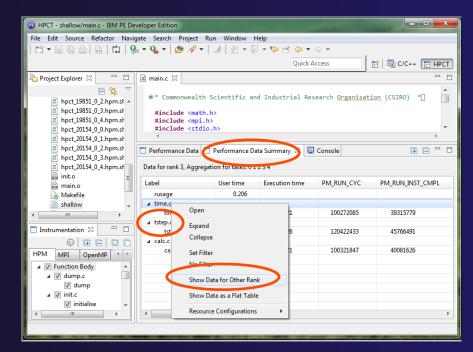


HPCT-31

### View HPM Performance Data 2

#### Open the **Performance Data Summary** view

- When viewing multiple tasks
  - Right click on any entry in
     Performance Data Summary view
  - Select Show Data
     for Other Rank
  - Select task/pid from dropdown and click
     OK





HPC Toolkit

HPCT-32

### View HPM Performance Data 3

- To view additional metrics
  - Select instrumentation point in Performance
     Data Summary view
  - Right click
     instrumentation point
  - Select Show Metric
     Browser view
- The Metric Browser view opens
  - Shows data for all tasks

🗖 Performar	ice Data Sum	nmary 🛛	📃 Console	e) 🖏 Progress	🔨 Performance Data Manager	Œ.	
Data below	is for rank 3 for tasks: 1 :	234					
Label		201	User time		Execution time	PM_RUN_CY	κ.
rusage			4.525		Execution and		<u> </u>
😑 time.c							
timet	e i pen				1.200	48251221	161
😑 to en.c					1.000	7000004	100
tstep = calc.c	Collapse				1.809	72609241	190
calcu					1.230	49434534	430
	Set Filte						
	Show Da	ata for Oth	ner Rank				
	Show D:	ata ao a E	lət Təhle				
(	Show M	etric Brow	/ser				
				(	4		
	Performance (			-	Performance Data Mana 🔲 Me	•	
Ta 1	sk Thread 1074		_INST_CMPL	PM_LD_REF_L1 295734382		PM_ST_MISS_L1 46723087	PM_LD_MISS_L 213429
3	1074		727996	701106759		46713860	202750
2	1074		196370	700998721	8747.722	46710531	80135
4	1074	21555	591697	295817547	2999.205	46711472	98632
<b>&gt;</b> -							
<			1111				>

### View HPM Performance Data 4

- Pick sort column by selecting column title
- To add or delete visible metrics
  - + Right click in Metric Browser view
  - Select Show Other Metrics
  - + Hide or show metrics using Filter Dialog

🗖 Perf	🗖 Performance Data Sum 🛭 🗐 Console 🕞 Progress 📧 Performance Data Mana 📄 Metric Browser (timete 🙁 👘 🗖								
Task	Thread	PM_RUN_INST_CMPL	PM_LD_REF_I	Number of loads	per load miss	M_ST_MISS_L1	PM_LD_N		
1	1074030000	2157566742	295734382	1385.624		46723087	213		
4	1074030000	2155591697	295817547	2999.; Sn	ow Other Metrics	6711472	98		
3	1074030000	2155727996	701106759	3457.986	- FilterDialog		X		
2	1074030000	2155496370	700998721	8747.722	Current Hidden Metrics		Current Display Metrics		
					Overhead time Initialization time		PM_RUN_INST_CMPL PM_LD_REF_L1		
<u> </u>							Number of loads per load miss PM_ST_MISS_L1		
<		1111					PM_LD_MISS_L1		
						Move to S	how> hstructions per run cycle		
						Move to H	ide < Jumber of load/stores per L1 miss		
							Execution time Utilization rate		
							Number of stores per store miss PM_ST_REF_L1		
						CLOSE			
PC To	oolkit						HPCT-34		

### View HPM Performance Data 5

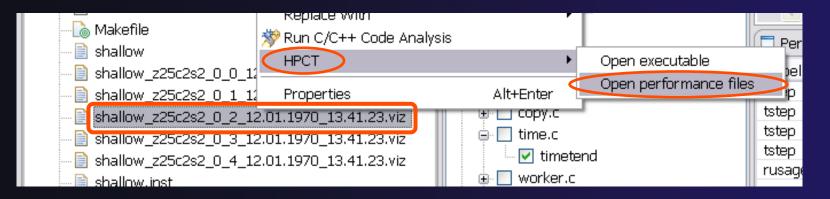
<ul> <li>Performance I</li> <li>Data below is fo</li> <li>Aggregation for</li> <li>Label         <ul> <li>rusage</li> <li>time.c</li> </ul> </li> </ul>	r rank 3	Cons		- Progress		nance Data Ma Execution time			ser (timete PM_RUN_C	YC	ta	Rig Rig Pe Su Sel	ow all o in a ta ht click rforma mmary ect Sh	ble in ince D view ow Da	Data
timeter	Open					1.200			4825122	161		a F	lat Ta	ble	
😑 tstep.c 🛛 –	Open											orfo			
tstep	Expand					1.809			7260924	160			rmane		
😑 calc.c	Collapse										D	etai	view	opens	S
calcuvz	Set Filter No Filter					1.230			4943453	430			ata by d table		
	Show Data for (	Other Ra	ank								de	esire	d table	e colu	mn
<	Show Data as a	i Flat Tal	ble							>					
	Show Metric B	Perform	ance Data	a Summary 🗍	📃 Console 📼 Pr	ogress 🚺 Perfori	nance Data Ma	nager 🗖 M	etric Browser (t	timetend) 🗖 F	Performance Data	Detail 🛛			- 8
		Label			nction   User time	System time	ru_minflt	ru_majflt	ru_nvcsw	ru_nivcsw			PM_RUN_INST_CMPL		
		tstep		tstep.c							1.908	7660207	2564040522	79393668	92607749
		tstep		tstep.c							1.809	7260924	2560817069	81341692	93396997
		tstep		tstep.c							1.611	6465470	2560369918	76502501	93243548
		tstep		tstep.c							1.741	6990281	2560506225	79150476	92814453
		rusage	1		4.5		832	0		15					
		rusage	3		4.5		5204 787	0		172 26					
		rusage	2				/8/	0		25					
		rusage timetend		time.c	4.6	06 0.050	828	U	84	4/	1.160	4661488	2157566742	213429	46723087
		timetend		time.c							1.160	4825122	215/500/42	213429	46713860
		timetend	-	time.c							1.200	4825122	2155496370	80135	46710531
		timetend	-	time.c							1.128	4706886	2155591697	98632	46711472
		calcuvzh		calc.c							1.169	4698454	2204318186	125518	62289960
		calcuvzh	-	calc.c							1.109	4943453	2202466613	130776	62286418
		calcuvzh		calc.c							1.127	4530959	2202197426	67592	62288237
		calcuvzh	-	calc.c							1.193	4796956	2202197420	83523	62286187
											2,250			00020	000000
		<													>

HPC Toolkit

HPCT-35

### **Re-opening Performance Data**

- To re-open Performance Data files:
- Select Project Explorer view
- Select one or more data (.viz) files
- Right click over selected files
- Click HPCT in popup menu
- Click Open performance files in second menu





### MPI Profiling and Tracing

HPCT-37

### Lab Exercise Note

- For the hardware performance counter exercise m and n = 512 in decs.h to get useful event counts and times
- Change m and n to 8 in decs.h and rebuild shallow to reduce trace size to a manageable level

+m,n = 32 is ok

### Collect MPI Data

#### Open Profile Configuration dialog

HPC Toolkit

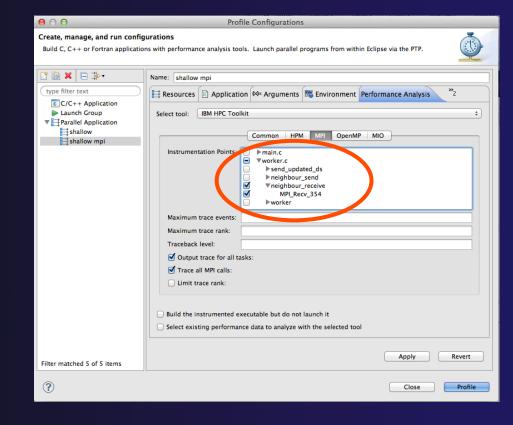
- + Example: Reuse profile configuration created for hardware performance counters
  - + To remove HPM info: HPM tab, uncheck Function Body & reset DRM "MIPS" to blank and reset 'generate vis. Files'
  - + Or can copy profile configuration to keep both configs
- Same setup as hardware performance counters except you select MPI in Performance Analysis tab of profile configuration

00	Profile Configurations						
Create, manage, and run configurations Build C, C++ or Fortran applications with performance analysis tools. Launch parallel programs from within Eclipse via the PTP.							
Y     Image: Second seco	Name: shallow mpi						
	Maximum trace events:         Maximum trace rank:         Traceback level:         Ø Output trace for all tasks:         Ø Trace all MPI calls:         Limit trace rank:						
Filter matched 5 of 5 items	Build the instrumented executable but do not launch it     Select existing performance data to analyze with the selected tool						
?	Close Profile						

HPCT-39

### Collect MPI Data (2)

- Select MPI tab
- Select instrumentation points
  - + By call site
- Select checkbox to instrument this point
  - Be selective to reduce overhead
- For example:
  - Within neighbour\_receive
  - Select MPI\_Recv\_##



### Collect MPI Data 3

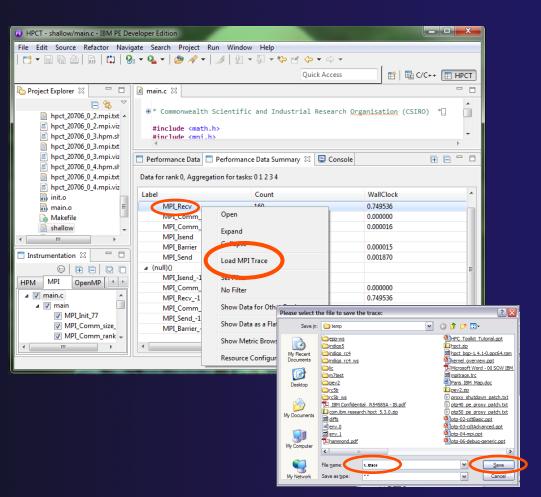
# Check Output trace for all tasks Check Trace all MPI calls

HPC

Profile Configurations				X
Create, manage, and run configuration Build C, C++ or Fortran applications with		allel programs from within Eclipse via the PTP.	٩	
Image: Second secon	Name: shallow	ments 🚾 Environment (Performance Analysis 🛛 🧐 TAU) Para Data Collection   PPW Compiler Wrapper - UPC   PPW Progr.		
	Maximum trace events: 30000 Maximum trace rank: Traceback level: Coutput trace for all tasks. Trace all MPI calls: Limit trace rank:			
Filter matched 4 of 4 items			Apply Revert	
?			Profile Close	
ect <b>Profile</b> to file analysis	o run the	<ul> <li>Open Visualization F</li> <li>Do you want to automatically open these visuali /u/tibbitts/shallow/hpct_5284_0_1.mpi.viz /u/tibbitts/shallow/hpct_5284_0_2.mpi.viz /u/tibbitts/shallow/hpct_5284_0_3.mpi.viz /u/tibbitts/shallow/hpct_5284_0_4.mpi.viz /u/tibbitts/shallow/hpct_5284_0_0.mpi.viz</li> </ul>		
lkit			No	res PCT-4

### View MPI Profile Data

- Performance Data
   Summary view opens automatically
- Works similarly to viewing hardware performance counter data
  - Right click in view to open metric browser, show flat table, view different task's data
- Right click somewhere in Performance Data Summary view
- Select Load MPI Trace in popup menu
- Select path to save trace file on *local* system

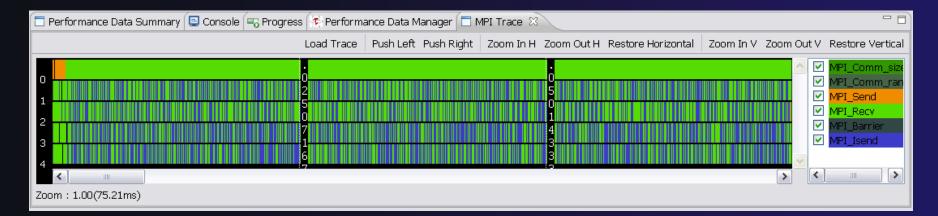


HPC Toolkit

HPCT-42

### View MPI Trace Data

- Timeline view of MPI function calls
- MPI Function calls color coded matching list of right
- Exclude functions from trace by clicking checkboxes
- Zoom in and out using buttons in title bar
- Right click on an event box to see details for that event



### In Summary

#### Set of performance tools integrated with Eclipse and PTP

- + Hardware performance counter profiling
- MPI profiling and tracing
- OpenMP profiling
- I/O profiling and tracing
- Application CPU time profiling
- Binary instrumentation tools

# **IBM Parallel Debugger**

#### Objectives

- □ Introduce the IBM Parallel Debugger
- □ Learn how to use the debugger features

#### Contents

- □ Overview of debugger architecture and features
- □ Lab #1: Scavenger Hunt
- □ Lab #2: Shallow
- □ Lab #3: Sample Sort

# **DARPA** Challenge

### IBM's PERCS

- □ Productivity, ease-of-use
- Debug applications executing at Petascale
- □ Conventional 'serial' debug overwhelmed

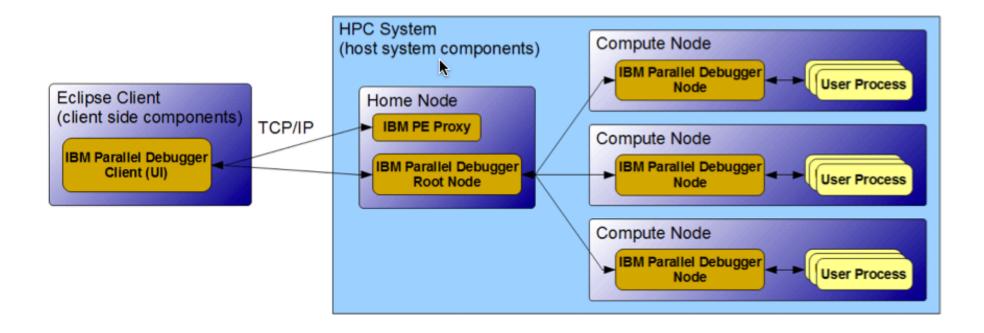
"Debugging code on a parallel machine with hundreds or thousands of cores creates unique problems, and may be the biggest single challenge facing parallel programming"

- Charles Holland [DARPA], The Economist, June 2011

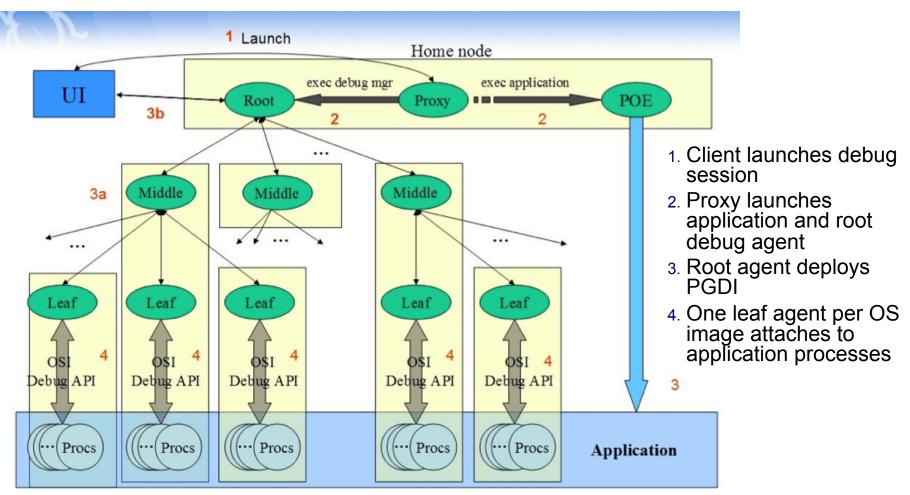
# About IBM ParDeb

- Utilizes mature serial debug engine technology
   idebug +15 years in development
- Parallel Group Debug Infrastructure (PGDI)
   Tree topology for efficient aggregation/filtering
- Customized for programming models
   MPI, UPC, X10, openMP
- Efficient use of UI resources (pixels, mem, etc.)
- Emphasis on grouping

# Parallel Debugger Architecture



# **Debugger Execution Environment**



PGDI = Parallel Group Debug Infrastructure

Debug-4

# Debugging at Petascale (1/2)

1,000,000 (1M) execution threads
How can they be represented in the UI?
How can the user operate on them?
Need to be able to operate on a subset of threads
How can the user find the defect?
Not practical to examine each thread one by one

# Debugging at Petascale (2/2)

- Organizing the threads into groups
   Based on common characteristics of thread state and data Debug
   Can't be done manually
   What about thread state and data changes?
  - This only works if the debugger does all the heavy lifting

# Debug Groups

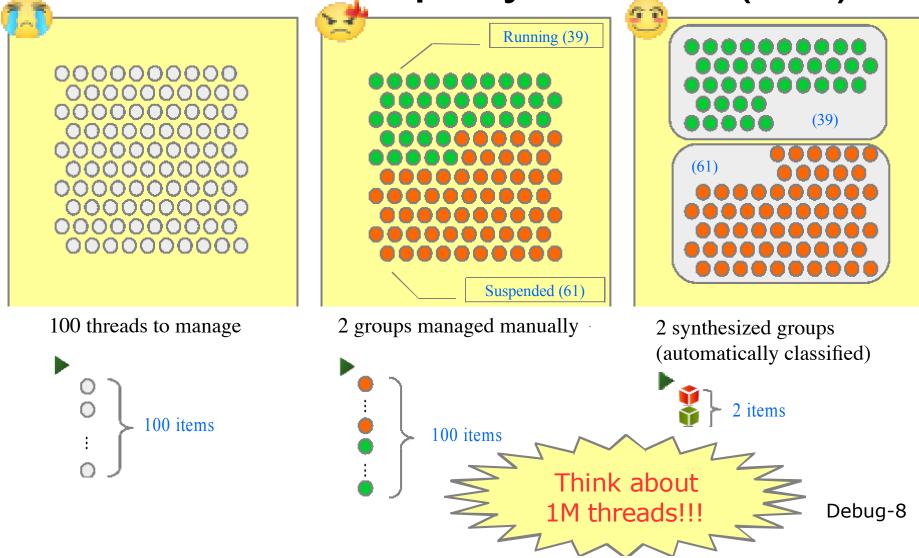
- Debug groups are dynamic collections of user threads
- All threads belong to at least one group,
- Threads join and leave groups as session progresses

#### Group types

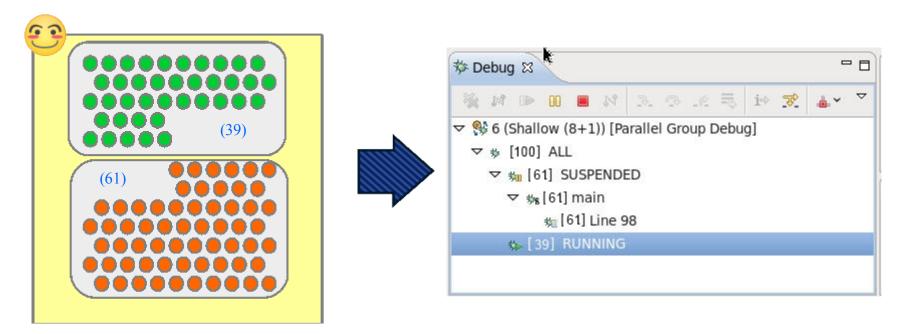
- □ ALL all user threads
- Debug state application states (e.g. SUSPENDED)
- Function location suspended in a function or method
- □ Line location suspended on a line in a source file
- □ Breakpoint suspended on a breakpoint
- □ Stack threads that share a similar call stack
- □ Expression threads with common data property
- □ Distribution threads with a variable within a certain range
- □ Static copy of some other group, membership never changes

#### **IBM** Parallel Debugger

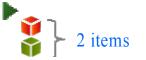
### Scalable Group Synthesis (1/4)



# Scalable Group Synthesis (2/4)



2 synthesized groups (automatically classified)



# Scalable Group Synthesis (3/4)

- Groups are synthesized by applying a set of conditions to an existing group
  - □ Group<sub>ALL</sub> and Suspended => Group<sub>Suspended</sub>
  - $\Box$  Group<sub>ALL</sub> and Running => Group<sub>Running</sub>
- Members join/leave groups dynamically
- Membership is not enumerated
  - □ PGDI encodes membership during synthesis
  - □ Group representative available to UI
- Billions of groups can be reserved
  - □ Light weight
  - □ Group vectors/arrays

# Scalable Group Synthesis (4/4)

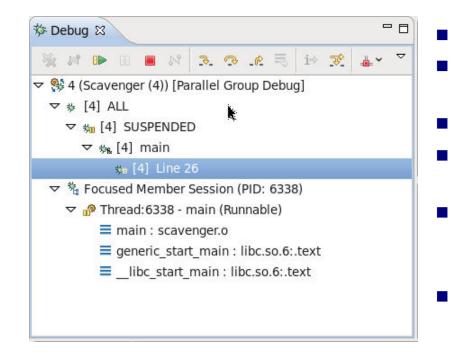
- Problem investigation strategies
  - □ Divide and conquer
  - □ Odd man out
  - Outliers
  - □ Etc...
  - □ Can be applied in combination

#### IBM Parallel Debugger

### **Debug Perspective**

📬 🕶 🗟 🕼 🛔 🎄 🕶 🔕 🕶 🚱 🕶 🥭	🔗 🔹 👔 🕈 💱 😓 🗢 🗢 🕶		12 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
F Debug 🖾 👘 🗖	🙀 Parallel Debug Groups 😫 🗧		rib 🐮 Group Deta 🐮 Data Eleme 🚏 Parallel Call 👘 🧮
🎉 🖉 🗈 🖩 🖉 🌫 🔿 🧟 🤯 🕌 📲 🖉	Zoom Group	~	🖄 🕫 🕞 🖉 🛪 🙀 📑 🗹 🍓 🔻
<ul> <li>Sample Sort) [Parallel Group Debug]</li> <li> <ul> <li></li></ul></li></ul>	<ul> <li>\$\$ [4] ALL</li> <li>BREAKPOINTS</li> <li>\$\$ STATES</li> </ul> Parallel Stacks \$\$ Zoom Group   \$\$ a \$\$ a \$\$ [4]xdupc_main (stackDepth=4) \$\$xdupc_main (stackDepth=4) \$\$xd	Name       Image: Nam       Image: Name	Value 0 1 1 0×00000FFFE4684178
<pre>driver.upc &amp; driver.upc &amp; 75 /* 76 77 CLOCK(tstart); 78 switch (codeTuningLevel) { 79 case EXPERIMENTAL: // fall through 80 case TUNED: init(); break; 81 case SIMPLE: // fall through 82 default: init_naive(); 83 } 84 CLOCK(tend); 85 86 if (timing &amp;&amp; MYTHREAD==0) 87 fprintf(stdout, "Initialize Array: %4.2f\n", 88 upc_barrier; 89 90 if (N&lt;=512 &amp;&amp; MYTHREAD==0 &amp;&amp; 0) { </pre>		· ·	Outline Project Explorer 🛛 📄 😫 🔝 🖓 🖓 🦉 🖓 😵 🦉 🖓 🎉 Sample Sort 🚰 Scavenger 🚰 Shallow
91 fprintf(stdout, "ARRAY (BF=%d, N=%d):\n ", B 32 Console 23 @ Tasks Problems @ Executables mple Sort [Parallel Group Debug] IBM PE@Workshop P7IH System: job Verification of result is enabled. Debug Enabled. Debug Level 2.		• • •	■ × ¾   № 5 (-) (-) - (

# Debug View



- Used to control groups of threads
- Debug actions operate on threads associated with selected group
- Group name indicates type
- Number of threads in group is shown in []'s
- Focused member section shows stack frame of representative from selected group
- Group selection drives
  - Source View
  - Parallel Stacks View
  - Variables View

# Source/Editor View

	sca	venger.c 🕱	- 0
	36	long age;	^
	37		
8	38	<pre>something = doSomeMoreMagic();</pre>	
	39		
	40	<pre>switch(child)</pre>	
	41	{	
	42	<pre>case 0: /* execute unit of code 1 */</pre>	
۵	43	num = foo();	
	44	num = goo(4);	
	45	break;	
	46	<pre>case 1: /* execute unit of code 2 */</pre>	
۵	47	<pre>num1 = foo other file('l');</pre>	
	48	ally = ( <b>char</b> ) num1;	=
	49	age = light other file(53);	22
	50	break;	
	51	<pre>case 2: /* execute unit of code 2 */</pre>	
۵	52	<pre>foo header file('b');</pre>	
	53	getThis = doSomeMagic();	
	54	break;	
	55	<pre>case 3: /* execute unit of code 2 */</pre>	
۵	56	abc = nowWhat();	
	57	break;	
	58	default: /* execute default action */	
	59	break:	~
	8	III	>

- Synchronized with debug view
- Left Margin
  - Breakpoint markers
  - Execution context markers
- Right Margin
  - □ File level execution markers
- Line highlighting for suspended threads
  - Orange shading
    - Active thread(s) selected in Debug view
  - Blue dashed box
    - Active thread(s) not selected in Debug view
  - Green shading
    - Thread(s) selected in Focused Member section

#### Debug-14

# **Parallel Stacks View**

- Shows merged call stacks for the group selected in the Debug view
- Works with debug control actions to step or resume threads
- Toggle function level or line level comparison
- Toggle to select call hierarchy order
- Stack selection drives
  - □ Source View
  - □ Group Details View

		-				_
$\equiv$ Parallel Stacks 🔀	Zoom Group	te:	<b>f</b> .	~		
▼ ﷺ [1] main (stackDepth=2)						П
📃 main : scavenger.c			4			
start+0x19 : scavenger:	.text					
▶ ‡ [1] main (stackDepth=2)						
▶ ‡ [1] main (stackDepth=2)	▶ #= [1] main (stackDepth=2)					
▶ 1 main (stackDepth=2)						

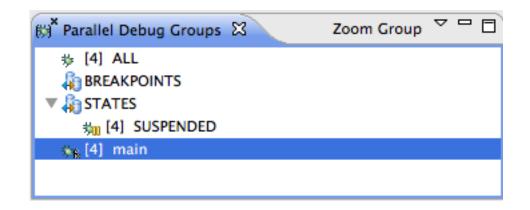
# Variables View

Name	Value	Actual Type
😑 argc	1	int
🛨 👮 argv	0x00000FFFF87F888	char**
😑 chunk_size	0	int
🔩 di	0.39269909	float
🗢 dj	0.0	float
🛨 😑 dummy1	{ 4.4779894E-39, 1.4349296E-42, 4.3454546E-39, 1.434	4 float[16]
🗉 😑 dummy2	{}	float[16][16]
🕀 🗢 h	{}	float[16][16]
😑 i	0	int
😑 j	0	int
🗉 🔍 master_packet	{ 139648, 0, 0, 0 }	int[4]
😑 nxt	0	int
н 🗢 р	{}	float[16][16]
🕀 👮 p_start	{ 7.0064923E-45, 0.0, 1.4012985E-45, 0.0, 9.9743623E-	float[16]
😑 pi	3.1415927	float
🕀 😑 pold	{}	float[16][16]
🛨 👮 pold_start	{ 0.0, 5.7383172E-42, NAN, 1.793662E-43, 3.7900614E-	· float[16]
😑 proc_cnt	525206536	int
😑 prv	0	int
🕀 😑 psi	{}	float[16][16]
🕀 😇 psi_start	{ 2.1966755E-40, 5.7383172E-42, NAN, 0.0, 0.0, }	float[16]
🛨 👮 res_type	0×00000000000000	MPI_Datatype*
😑 tid	0	int
, 😑 toi	6.2831855	float

- Displays variables from representative member of selected group
- Shows variable value and type information (if available)
- Yellow highlight when value is modified during execution
- Value can be edited, changes will be reflected when execution continues
- Data structures are represented using hierarchical tree format
- Variable values can be autorefreshed at regular intervals

# Parallel Debug Groups View

- Acts as a clipboard area
- Interesting groups can be saved and monitored during a debug session
- Right-click on group in debug view and select Save Group
  - □ Will place group in Parallel Debug Groups view



#### IBM Parallel Debugger

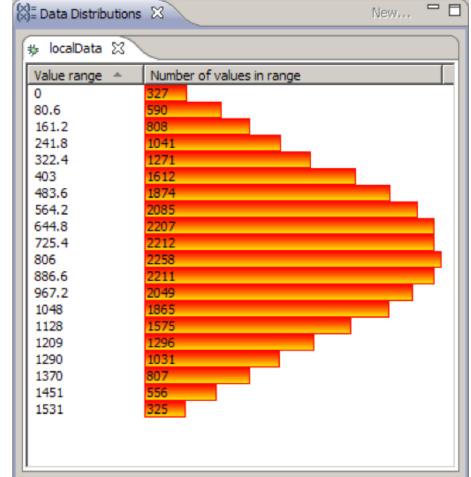
# **Data Elements View**

- Used to retrieve a number of specific data values from a large set of data elements
- Data elements can be
  - □ Scalar local variables
  - Scalar elements of shared or local array
- Elements are retrieved from all suspended threads that have the variable in scope
  - □ Value matches value range
- Application must be built with FD2 Debug Extensions

Element	Value	
= L myId		
myId	2	<b>A</b>
myId	1	
🔷 myId	3	
myId	0	
or each element X in myId,	show only ele	ments where:
X < 4	Show Shiry Cit	menoo where.
elements match the filter	(4 elements a	shown)

# **Data Distributions View**

- Histogram of data element values
- Each bar corresponds to value subrange
  - Length of bar represents number of elements in range
- Upper and lower bounds can be calculated automatically or specified manually
- Distributions can be created on
  - Scalar local variables
  - Scalar elements of a shared or local array
- Requires application built with FD2 Debug Extensions



#### IBM Parallel Debugger

# Parallel Group Debug Configuration

Debug Configurations	igurations		Ť
Type filter text	Name: sample sort	ation 🔅 Parallel Group Debug 🛛 🕬= Arguments 🤖 Source	) <sup>»</sup> 2
C/C++ Remote Applica Fortran Local Applicatic Java Applet Java Applet Java Application Parallel Application Parallel Group Debug Sample sort Remote Java Applicatic	Debugger home directory: Debugger UI hostname: Debugger UI port:	/opt/IBM/pardeb/1.2/bin coopersvm.torolab.ibm.com 8888 Apply	Browse
Filter matched 13 of 13 items		Debug	

# Lab #1 – Scavenger Hunt

- Parallel debug perspective
- Debug view
  - □ Groups (ALL, Suspended, Function, Line)
  - Focused Member
    - Group representative's call stack
  - Debug controls (resume, step into, step over, etc...)
  - □ Breakpoints
  - Selection drives content of other views such as
    - Source view, Variables view, Parallel stacks view, etc...

# Lab #2 - Shallow

# Debug an MPI application MPI Debug Library MPI Error Handling

#### Reinforce basic debug skill set

Breakpoints

□ Stepping (step into, step over, step return)

Debug, code, build cycle

# Lab #3 – Sample Sort

### Debug a UPC application

- □ View shared variables
- □ Use of UPC Barrierpoints
- Diagnose errors
  - □ Program doesn' t run to completion
  - Determine cause and resolve through basic and advanced debugging features

### Other Tools and Wrap-up

#### ✦ Objective

- How to find more information on PTP
- Learn about other tools related to PTP
- See PTP upcoming features

#### Contents

- Links to other tools, including performance tools
- Planned features for new versions of PTP
- Additional documentation
- How to get involved

### Useful Eclipse Tools

- Linux Tools (autotools, valgrind, Oprofile, Gprof)
  - http://eclipse.org/linuxtools
- Python
  - http://pydev.org
- Ruby
  - http://www.aptana.com/products/radrails
- + Perl
  - http://www.epic-ide.org
- + Git
  - http://www.eclipse.org/egit
- ✤ VI bindings
  - Vrapper (open source) http://vrapper.sourceforge.net
  - viPlugin (commercial) http://www.viplugin.com

### **Online Information**

- IBM PE Developer Edition
  - http://ibm.co/tdM7QD
- Information about PTP
  - Main web site for downloads, documentation, etc.
    - http://eclipse.org/ptp
  - + Developers' wiki for designs, planning, meetings, etc.
    - http://wiki.eclipse.org/PTP
  - Articles and other documents
    - http://wiki.eclipse.org/PTP/articles

#### Information about Photran

- Main web site for downloads, documentation, etc.
  - http://eclipse.org/photran
- User's manuals
  - http://wiki.eclipse.org/PTP/photran/documentation

### Mailing Lists

#### PTP Mailing lists

- Major announcements (new releases, etc.) low volume
  - http://dev.eclipse.org/mailman/listinfo/ptp-announce
- User discussion and queries medium volume
  - http://dev.eclipse.org/mailman/listinfo/ptp-user
- Developer discussions high volume
  - http://dev.eclipse.org/mailman/listinfo/ptp-dev
- Photran Mailing lists
  - User discussion and queries
    - http://dev.eclipse.org/mailman/listinfo/photran
  - Developer discussions
    - http://dev.eclipse.org/mailman/listinfo/photran-dev

### Getting Involved

See http://eclipse.org/ptp
Read the developer documentation on the wiki
Join the mailing lists
Attend the monthly developer meetings

Teleconference Monthly
Each second Tuesday, 1:00 pm ET
Details on the PTP wiki

Attend the montly user meetings

Teleconference Monthly
Each 4<sup>th</sup> Wednesday, 1:00 pm ET

### **PTP Tutorial Feedback**

Please complete feedback form
Your feedback is valuable!

#### Thanks for attending We hope you found it useful