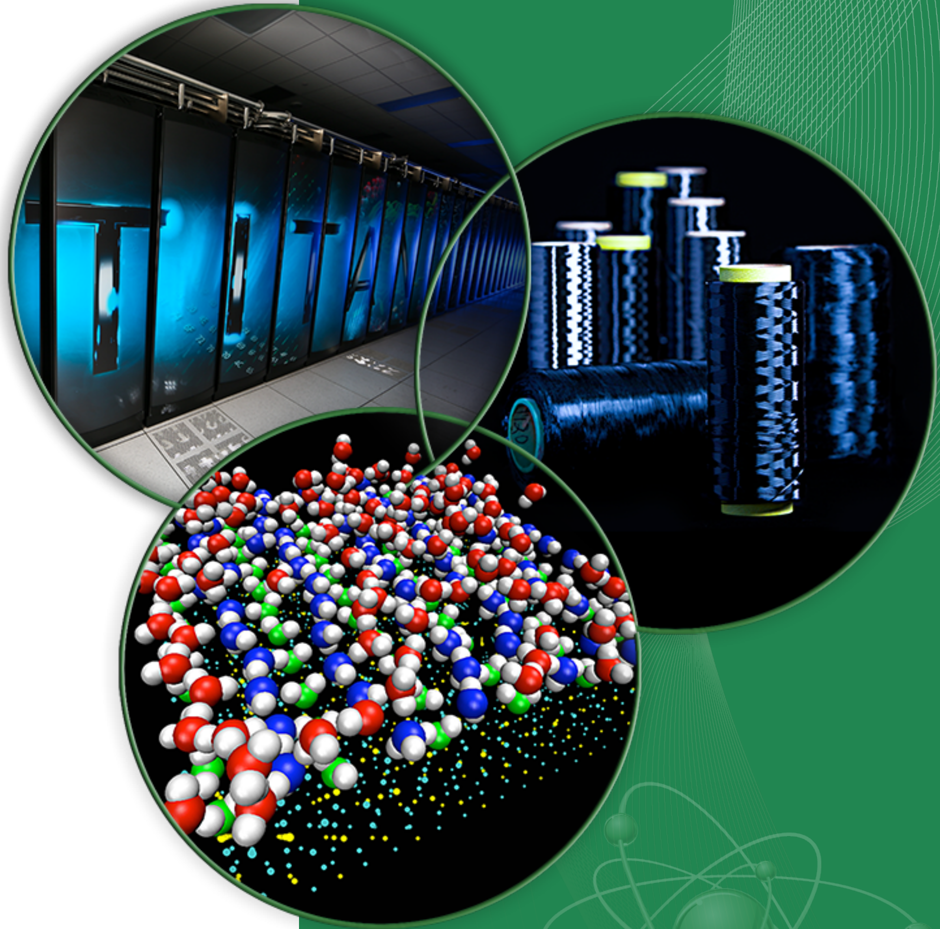
Eclipse for Science

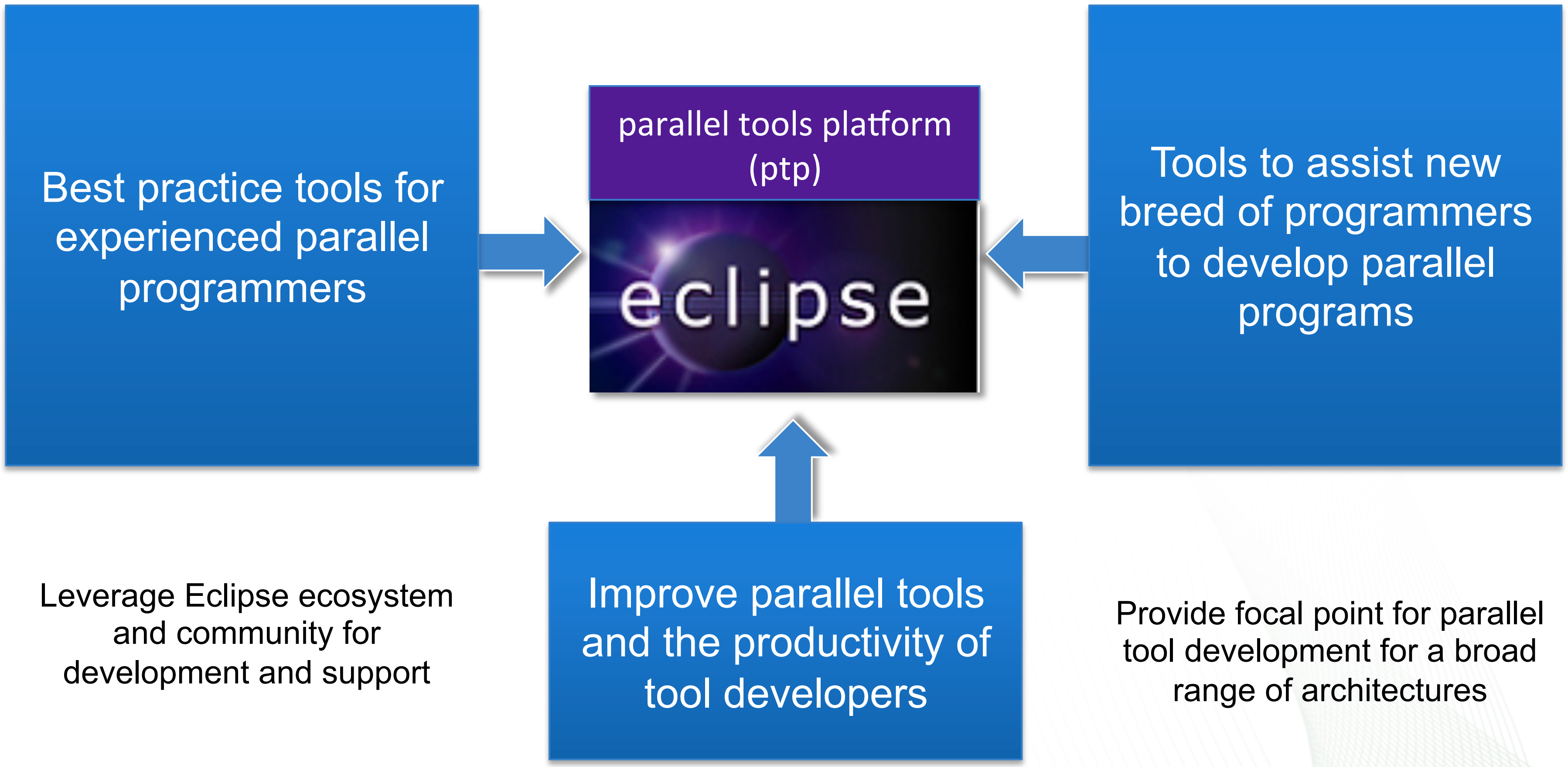
How the Parallel Tools Platform can enhance the development of scientific applications



OAK RIDGE
National Laboratory

Parallel Tools Platform

Enabling Parallel Application Development



Best practice tools for experienced parallel programmers

parallel tools platform (ptp)

Tools to assist new breed of programmers to develop parallel programs

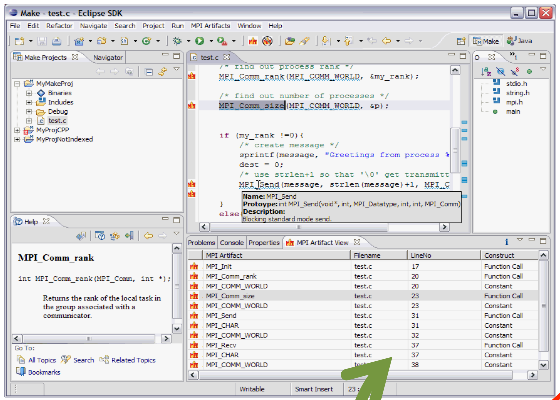
Improve parallel tools and the productivity of tool developers

Leverage Eclipse ecosystem and community for development and support

Provide focal point for parallel tool development for a broad range of architectures

PTP Application Development Cycle

Coding & Static Analysis



```
    /* find out process rank */
    MPI_Comm_rank(MPI_COMM_WORLD, &my_rank);

    /* find out number of processes */
    MPI_Comm_size(MPI_COMM_WORLD, &p);


    if (my_rank !=0){
        /* create message */
        sprintf(message, "Greetings from process %
        dest = 0;
        /* use strlen+1 so that '\0' get transmitt
        MPI_Send(message, strlen(message)+1, MPI_C

    }
    else
```

Name: MPI_Send
Protoype: int MPI_Send(void*, int, MPI_Datatype, int, int, MPI_Comm)
Description:
Blocking standard mode send.

MPI_Comm_rank

`int MPI_Comm_rank(MPI_Comm, int *);`

Returns the rank of the local task in the group associated with a communicator.

MPI Artifact	Filename	LineNo	Construct
MPI_Init	test.c	17	Function Call
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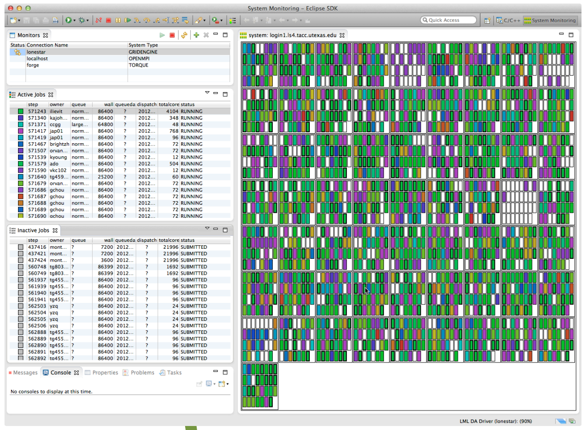
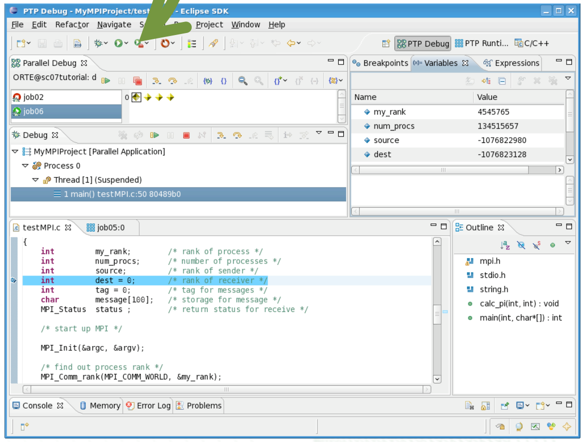
MPI_CHAR	test.c	31	Constant
MPI_COMM_WORLD	test.c	32	Constant
MPI_Recv	test.c	37	Function Call
MPI_CHAR	test.c	37	Constant
MPI_COMM_WORLD	test.c	38	Constant

Application Execution


System Monitoring - Eclipse SDK
Monitors
Active Jobs
Inactive Jobs
Console
Properties
Problems
Tasks
system: login1.ls4.tacc.utexas.edu
No consoles to display at this time.
LML DA Driver (lonestar): (90%)

Connection Name	System Type
lonestar	GRIDENGINE
localhost	OPENMPI
forge	TORQUE

Application Debugging



Name	Value
my_rank	4545765
num_procs	134515657
source	-1076822980
dest	-1076823128

MyMPIProject [Parallel Application]
Process 0
Thread [1] (Suspended)
1 main() testMPI.c:50 80489b0

testMPI.c
job05:0

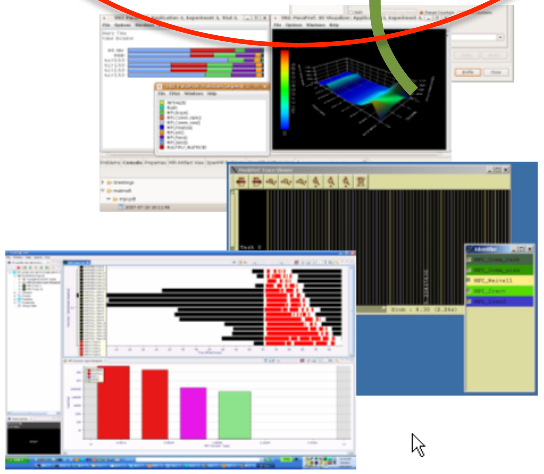
```
{
    int         my_rank;        /* rank of process */
    int         num_procs;      /* number of processes */
    int         source;         /* rank of sender */
    int         dest = 0;       /* rank of receiver */
    int         tag = 0;        /* tag for messages */
    char        message[100];   /* storage for message */
    MPI_Status  status ;        /* return status for receive */

    /* start up MPI */

    MPI_Init(&argc, &argv);

    /* find out process rank */
    MPI_Comm_rank(MPI_COMM_WORLD, &my_rank);
```

mpi.h
stdio.h
string.h
calc_pi(int, int) : void
main(int, char*[]) : int



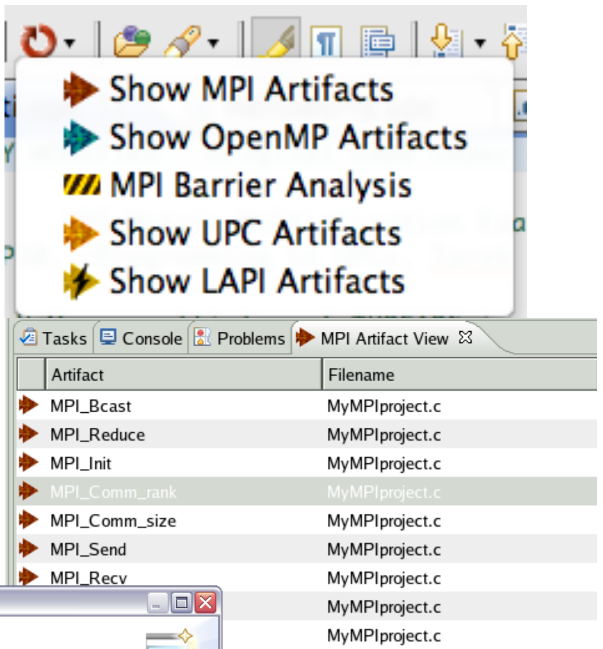
Dynamic & Performance Analysis

Coding & Static Analysis

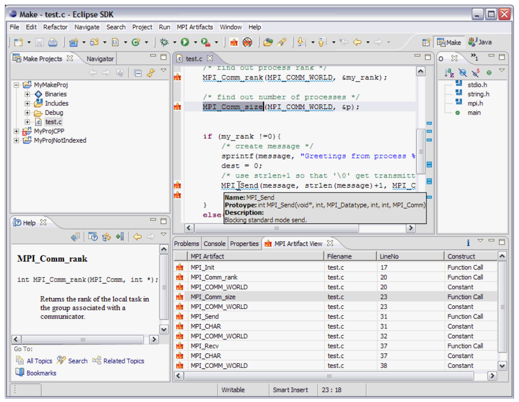
- Eclipse provides a wide variety of coding assistance tools
  - Project management, Editing and formatting, Navigation, Advanced searching, Refactoring, Version control
- C/C++ Development Tools (CDT)
  - Standard (Makefile) and managed builders, Support for arbitrary toolchains, Visual debugging using GDB, High level views (outline view, call hierarchy, type hierarchy, include browser), Refactorings
- Parallel Tools Platform (PTP)
  - Fortran, New project wizards (MPI, OpenMP) Content Assist, Hover help, Built-in API descriptions (MPI, OpenMP, LAPI, UPC), Location of parallel "artifacts" in code (MPI, OpenMP, PAMI, and UPC), Barrier analysis, Deadlock detection
- Python Development (PyDev)
  - Code completion, type hinting, refactoring, debugging, interactive console, unittest, code coverage, Django integration

Coding & Static Analysis

- Assistance tools to increase productivity of parallel programmers
  - New project wizards (MPI, OpenMP)
  - Content Assist (command/API completion), hover help, built-in API help descriptions in an html help “view” (MPI, OpenMP, LAPI, UPC)
  - Location of parallel “artifacts” in code: MPI, OpenMP, and UPC



Artifact	Filename
MPI_Bcast	MyMPIproject.c
MPI_Reduce	MyMPIproject.c
MPI_Init	MyMPIproject.c
MPI_Comm_rank	MyMPIproject.c
MPI_Comm_size	MyMPIproject.c
MPI_Send	MyMPIproject.c
MPI_Recv	MyMPIproject.c
	MyMPIproject.c
	MyMPIproject.c



```
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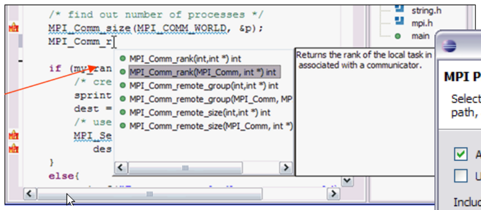

```
    /* find out number of processes */
    MPI_Comm_size(MPI_COMM_WORLD, &p);
    MPI_Comm_r

    if (my_ran
        /* cre
        sprint
        dest =
        /* use
        MPI_Se
            des
    }
    else{
```

- MPI_Comm_rank(int,int *) int
- MPI_Comm_rank(MPI_Comm, int *) int
- MPI_Comm_remote_group(int,int *) int
- MPI_Comm_remote_group(MPI_Comm, MP
- MPI_Comm_remote_size(int,int *) int
- MPI_Comm_remote_size(MPI_Comm, int *)

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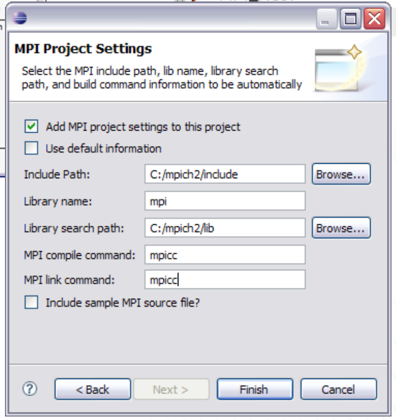


MPI Project Settings

Select the MPI include path, lib name, library search path, and build command information to be automatically

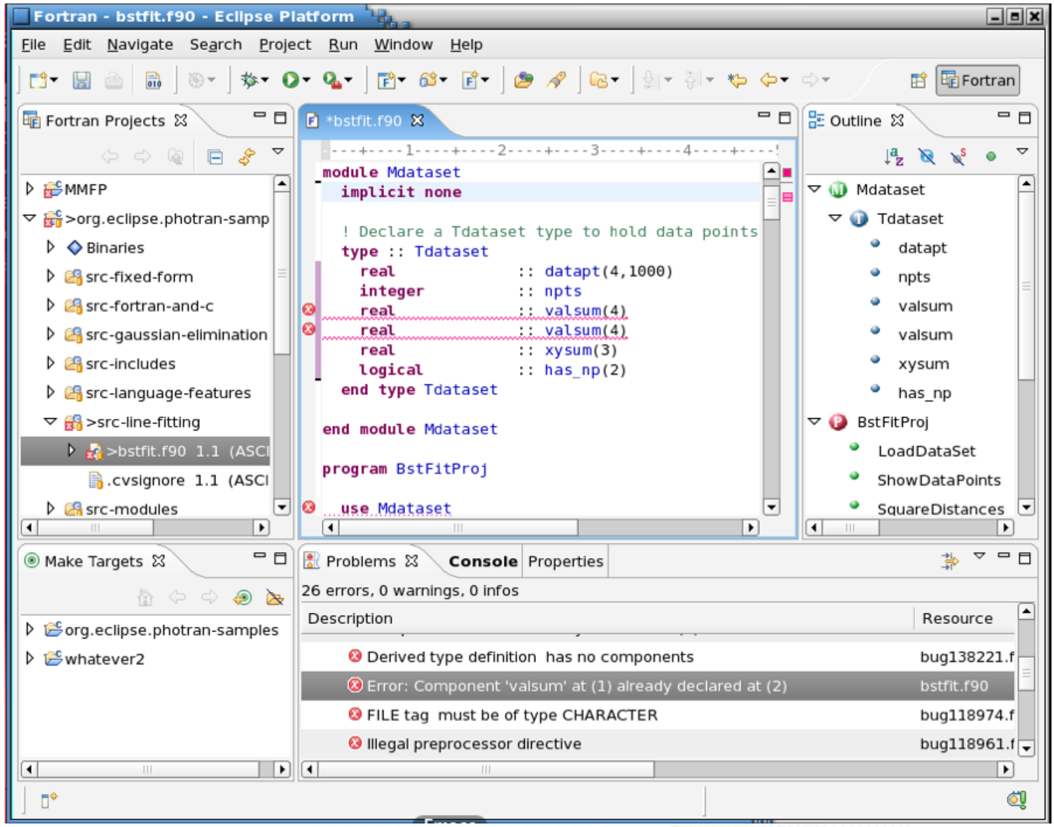
[✓] Add MPI project settings to this project
[ ] Use default information

Include Path:	C:/mpich2/include
Library name:	mpi
Library search path:	C:/mpich2/lib
MPI compile command:	mpicc
MPI link command:	mpicc

[ ] Include sample MPI source file?

Fortran Development Tools

- Photran features:
  - Supports Fortran 77-2008
  - Syntax-highlighting editor
  - GUI interface to *gdb*
  - Makefile-based compilation
  - Compiler error extraction
  - Outline view
  - Open declaration
  - Fortran refactorings
  - C preprocessor support



```
module Mdataset
  implicit none

  ! Declare a Tdataset type to hold data points
  type :: Tdataset
    real                :: datapt(4,1000)
    integer             :: npts
    real                :: valsum(4)
    real                :: valsum(4)
    real                :: xysum(3)
    logical             :: has_np(2)
  end type Tdataset

end module Mdataset

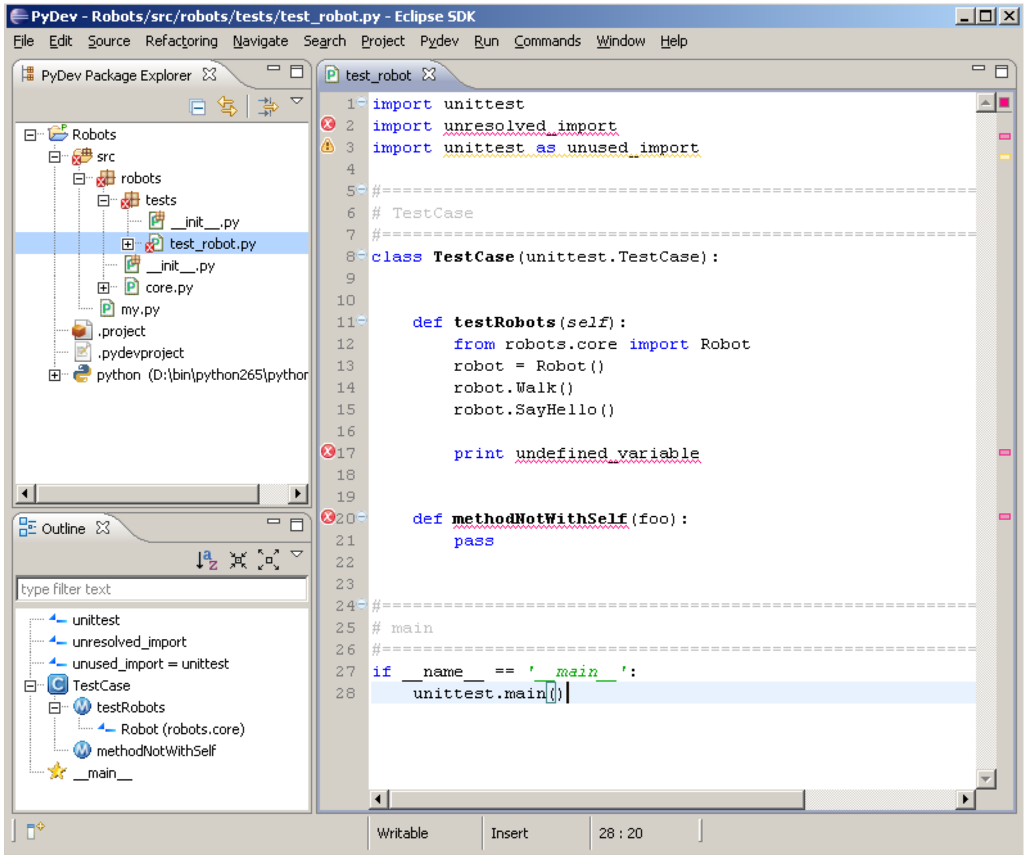
program BstFitProj

  use Mdataset
```

26 errors, 0 warnings, 0 infos

Description	Resource
Derived type definition has no components	bug138221.f
Error: Component 'valsum' at (1) already declared at (2)	bstfit.f90
FILE tag must be of type CHARACTER	bug118974.f
Illegal preprocessor directive	bug118961.f

Python Development



```
import unittest
import unresolved_import
import unittest as unused_import

#=======================================================================
# TestCase
#=======================================================================
class TestCase(unittest.TestCase):


    def testRobots(self):
        from robots.core import Robot
        robot = Robot()
        robot.Walk()
        robot.SayHello()

        print undefined_variable

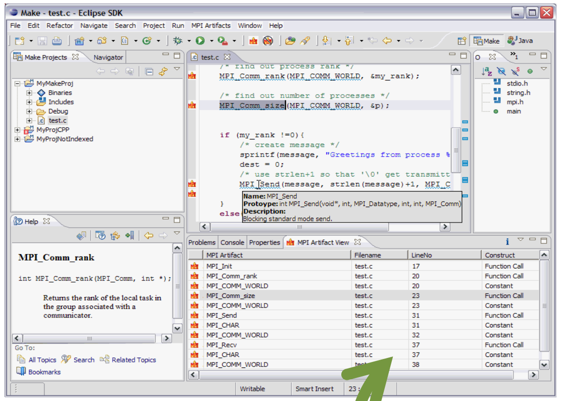

    def methodNotWithSelf(foo):
        pass


#=======================================================================
# main
#=======================================================================
if __name__ == '__main__':
    unittest.main()
```

- PyDev is a Python IDE for Eclipse
- Create/manage Python modules
- Full array of Eclipse editing features for Python
- Python debugger
- Interactive console with Python interpreter
- Integration with Python unittest and code coverage modules

PTP Application Development Cycle

Coding & Static Analysis



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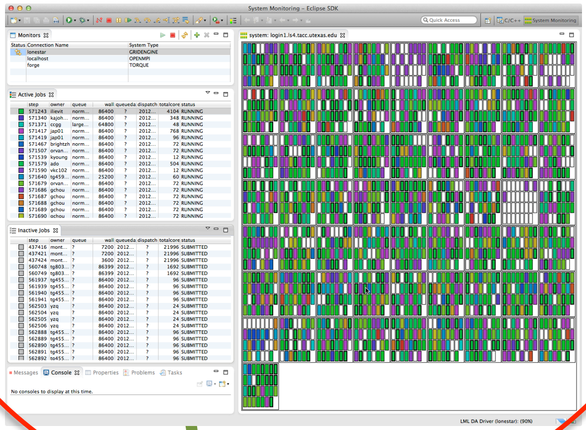
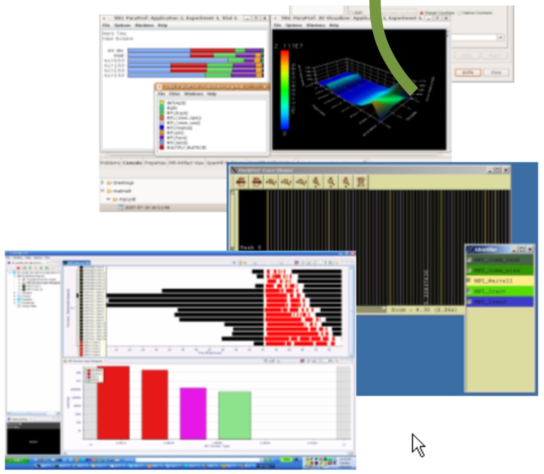
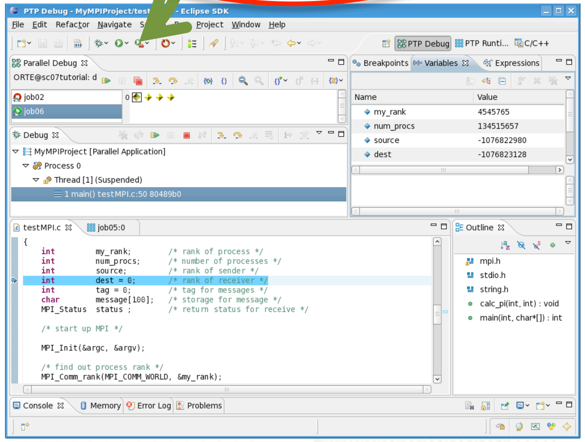
Application Execution



Dynamic & Performance Analysis



Application Debugging



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    int         source;         /* rank of sender */
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    int         tag = 0;        /* tag for messages */
    char        message[100];   /* storage for message */
    MPI_Status  status ;        /* return status for receive */

    /* start up MPI */

    MPI_Init(&argc, &argv);

    /* find out process rank */
    MPI_Comm_rank(MPI_COMM_WORLD, &my_rank);
```
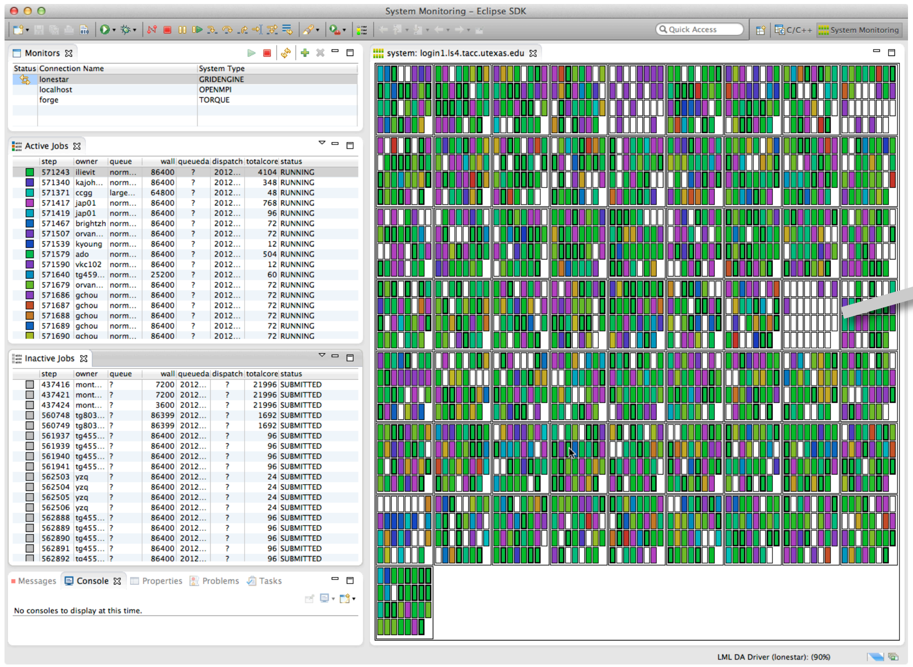

Application Execution

- Launching & Monitoring



System Monitoring – Eclipse SDK

Monitors

Status	Connection Name	System Type
	lonestar	GRIDENGINE
	localhost	OPENMPI
	forge	TORQUE

Active Jobs

	step	owner	queue	wall	queueda	dispatch	totalcore	status
🟩	571243	ilievit	norm...	86400	?	2012...	4104	RUNNING
🟪	571340	kajoh...	norm...	86400	?	2012...	348	RUNNING
🟦	571371	ccgg	large...	64800	?	2012...	48	RUNNING
🟪	571417	jap01	norm...	86400	?	2012...	768	RUNNING
🟦	571419	jap01	norm...	86400	?	2012...	96	RUNNING
🟦	571467	brightzh	norm...	86400	?	2012...	72	RUNNING
🟪	571507	orvan...	norm...	86400	?	2012...	72	RUNNING
🟦	571539	kyoung	norm...	86400	?	2012...	12	RUNNING
🟩	571579	ado	norm...	86400	?	2012...	504	RUNNING
🟪	571590	vkc102	norm...	86400	?	2012...	12	RUNNING
🟦	571640	tg459...	norm...	25200	?	2012...	60	RUNNING
🟩	571679	orvan...	norm...	86400	?	2012...	72	RUNNING
🟪	571686	gchou	norm...	86400	?	2012...	72	RUNNING
🟥	571687	gchou	norm...	86400	?	2012...	72	RUNNING
🟧	571688	gchou	norm...	86400	?	2012...	72	RUNNING
🟦	571689	gchou	norm...	86400	?	2012...	72	RUNNING
🟨	571690	gchou	norm...	86400	?	2012...	72	RUNNING

Inactive Jobs

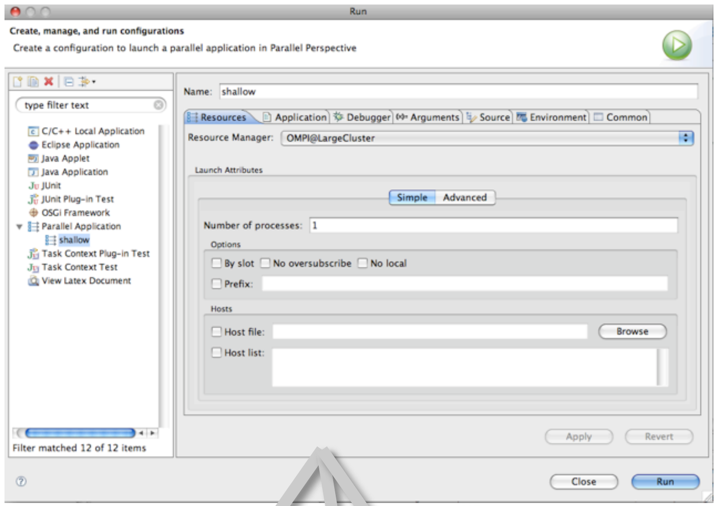
	step	owner	queue	wall	queueda	dispatch	totalcore	status
⬜	437416	mont...	?	7200	2012...	?	21996	SUBMITTED
⬜	437421	mont...	?	7200	2012...	?	21996	SUBMITTED
⬜	437424	mont...	?	3600	2012...	?	21996	SUBMITTED
⬜	560748	tg803...	?	86399	2012...	?	1692	SUBMITTED
⬜	560749	tg803...	?	86399	2012...	?	1692	SUBMITTED
⬜	561937	tg455...	?	86400	2012...	?	96	SUBMITTED
⬜	561939	tg455...	?	86400	2012...	?	96	SUBMITTED
⬜	561940	tg455...	?	86400	2012...	?	96	SUBMITTED
⬜	561941	tg455...	?	86400	2012...	?	96	SUBMITTED
⬜	562503	yzq	?	86400	2012...	?	24	SUBMITTED
⬜	562504	yzq	?	86400	2012...	?	24	SUBMITTED
⬜	562505	yzq	?	86400	2012...	?	24	SUBMITTED
⬜	562506	yzq	?	86400	2012...	?	24	SUBMITTED
⬜	562888	tg455...	?	86400	2012...	?	96	SUBMITTED
⬜	562889	tg455...	?	86400	2012...	?	96	SUBMITTED
⬜	562890	tg455...	?	86400	2012...	?	96	SUBMITTED
⬜	562891	tg455...	?	86400	2012...	?	96	SUBMITTED
⬜	562892	tg455...	?	86400	2012...	?	96	SUBMITTED

Messages | Console | Properties | Problems | Tasks

No consoles to display at this time.

system: login1.ls4.tacc.utexas.edu

LML DA Driver (lonestar): (90%)



Run

Create, manage, and run configurations

Create a configuration to launch a parallel application in Parallel Perspective

type filter text

- C/C++ Local Application
- Eclipse Application
- Java Applet
- Java Application
- JUnit
- JUnit Plug-in Test
- OSGi Framework
- Parallel Application
  - shallow
- Task Context Plug-in Test
- Task Context Test
- View Latex Document

Filter matched 12 of 12 items

Name: shallow

Resources | Application | Debugger | Arguments | Source | Environment | Common

Resource Manager: OMPI@LargeCluster

Launch Attributes

Simple | Advanced

Number of processes: 1

Options

☐ By slot ☐ No oversubscribe ☐ No local

☐ Prefix:

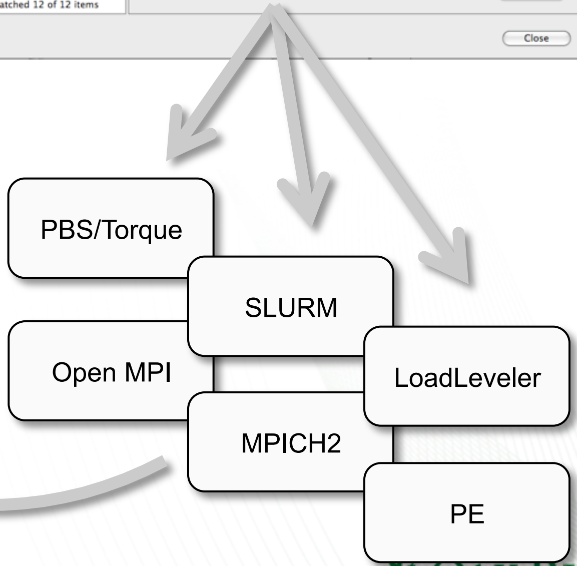
Hosts

☐ Host file: Browse

☐ Host list:

Apply Revert

Close Run



- Improves visibility into target system
- Single point of interface for launching and control
- Manages interaction with different runtime systems and job schedulers

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Application Execution

- Target Configuration Framework
  - Extensible framework for launching & monitoring
    - System and node status information
    - Job status (e.g. position in queue) & application status
    - Job submission & control
    - Debugger launch
  - Configuration files to support different resource managers
    - Job schedulers (LoadLeveler, PBS, Torque, SLURM, GridEngine)
    - Interactive runtimes (e.g. PE, Open MPI, MPICH2, MVAPICH)
    - Systems (AIX, Linux, Power, x86, BG/Q, Cray)
  - Local or remote system support
    - Command-line tools executed locally or via ssh connection

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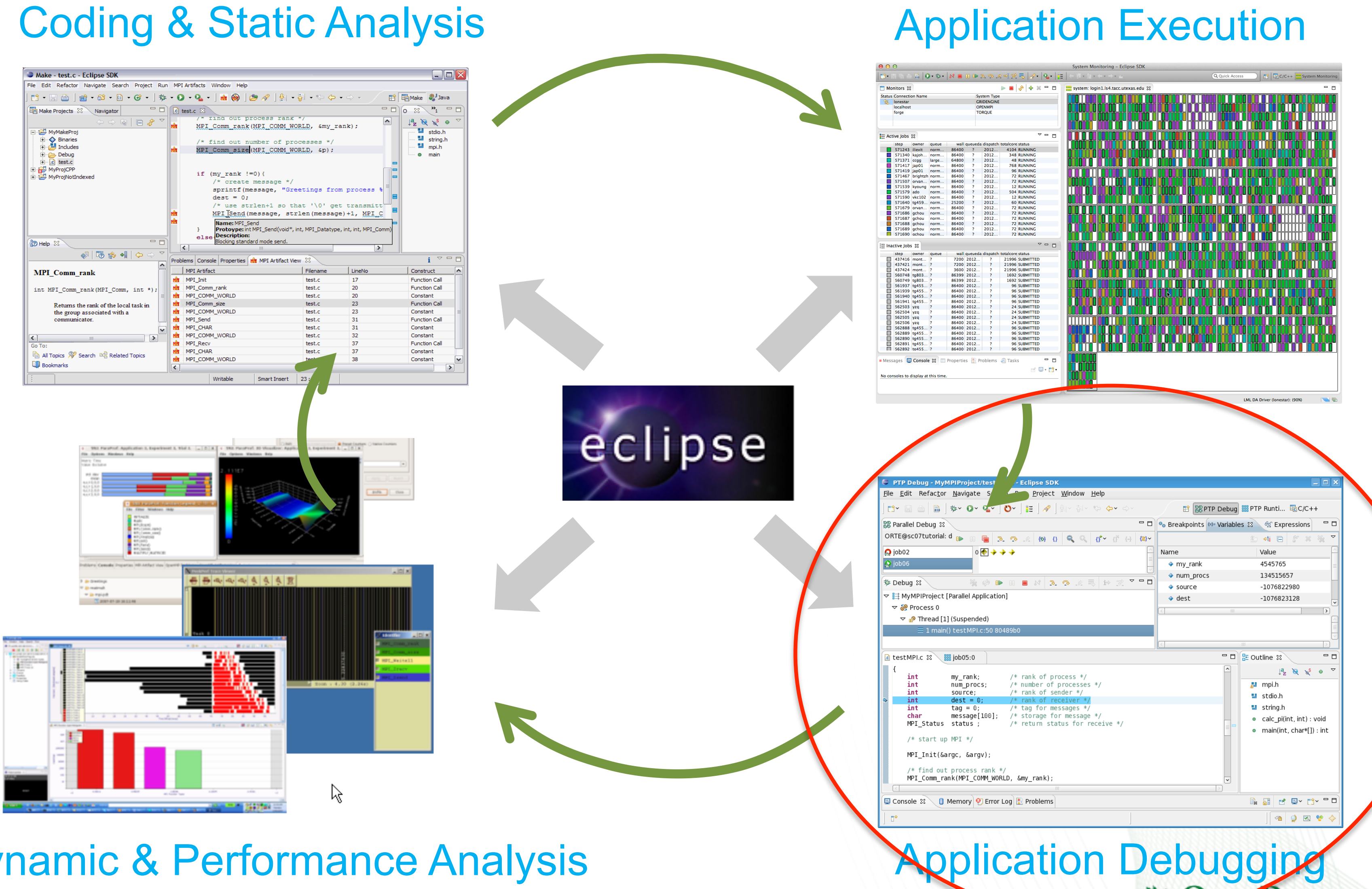
PTP Application Development Cycle



```
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```
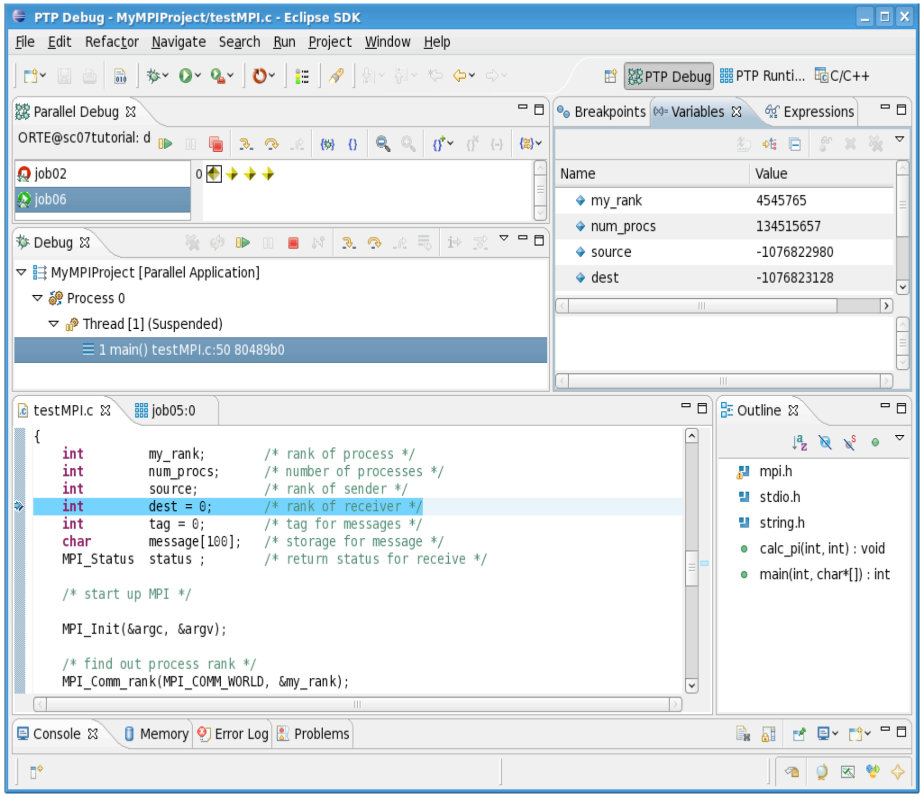

Application Debugging

- PTP Parallel Debugger



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  - Process 0
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Name	Value
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testMPI.c | job05:0

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Outline:
- mpi.h
- stdio.h
- string.h
- calc_pi(int, int) : void
- main(int, char*[]) : int

- Mid-scale integrated debugger
- Tightly integrated with Eclipse
- Supports debugging multiple jobs simultaneously
- Utilizes backend debugger (e.g. gdb) for low level operations
- Targeted at SPMD programming models
- Supports mixed MPI & thread debugging
- Single process and group operations
- Platform for building new debugging paradigms

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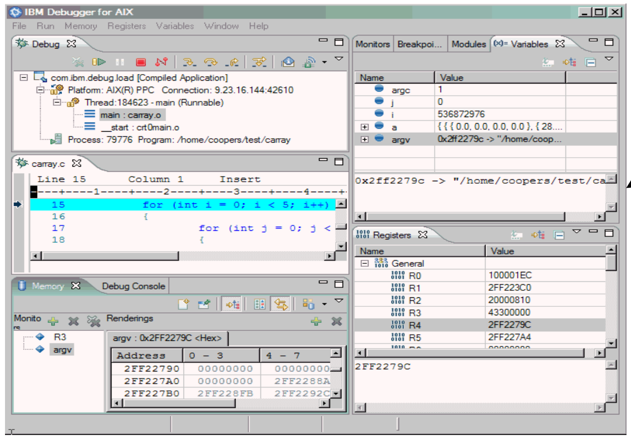
Application Debugging

- Scalable debugger using multicast reduction network
- Integrated with PTP and launched using target configurations
- Supports basic debug commands
- Uses gdb on backend



```
com.ibm.debug.load [Compiled Application]
  Platform: AIX(R) PPC  Connection: 9.23.16.144:42610
    Thread:184623 - main (Runnable)
      main : carray.o
      __start : crt0main.o
  Process: 79776  Program: /home/coopers/test/carray
```

```
Line 15        Column 1      Insert
----+----1----+----2----+----3----+----4----+
  15          for (int i = 0; i < 5; i++)
  16          {
  17                  for (int j = 0; j <
  18                  {
```

Name	Value
argc	1
j	0
i	536872976
a	{ { { 0.0, 0.0, 0.0, 0.0 }, { 28....
argv	0x2ff2279c -> "/home/coop...

```
0x2ff2279c -> "/home/coopers/test/ca
```

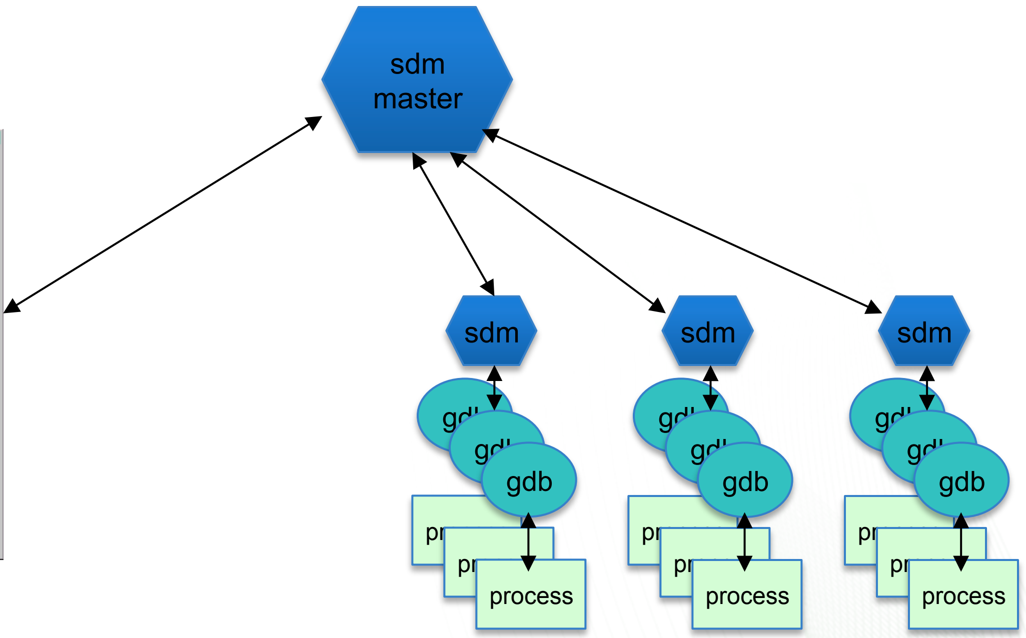
Name	Value
General	
R0	100001EC
R1	2FF223C0
R2	20000810
R3	43300000
R4	2FF2279C
R5	2FF227A4

```
2FF2279C
```

R3
argv

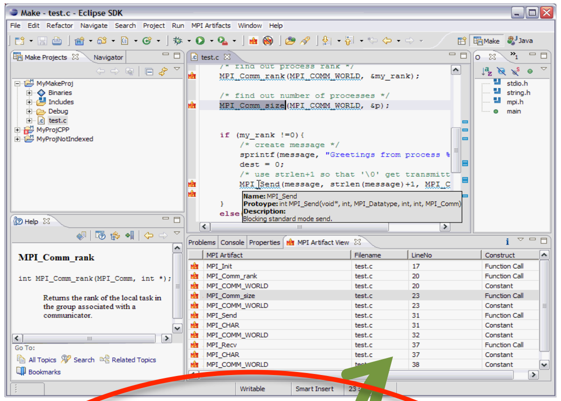
argv : 0x2FF2279C <Hex>

Address	0 - 3	4 - 7
2FF22790	00000000	00000000
2FF227A0	00000000	2FF2288A
2FF227B0	2FF228FB	2FF2292C



PTP Application Development Cycle=

Coding & Static Analysis



```
    /* find out process rank */
    MPI_Comm_rank(MPI_COMM_WORLD, &my_rank);

    /* find out number of processes */
    MPI_Comm_size(MPI_COMM_WORLD, &p);


    if (my_rank !=0){
        /* create message */
        sprintf(message, "Greetings from process %
        dest = 0;
        /* use strlen+1 so that '\0' get transmitt
        MPI_Send(message, strlen(message)+1, MPI_C
    }
    else
```

Name: MPI_Send
Protoype: int MPI_Send(void*, int, MPI_Datatype, int, int, MPI_Comm)
Description:
Blocking standard mode send.

MPI_Comm_rank

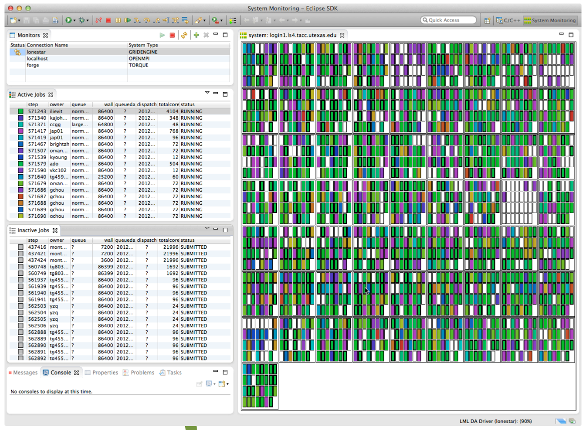
int MPI_Comm_rank(MPI_Comm, int *);

Returns the rank of the local task in the group associated with a communicator.

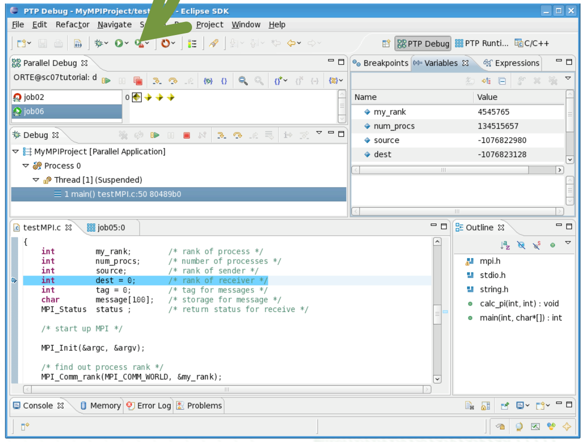
MPI Artifact	Filename	LineNo	Construct
MPI_Init	test.c	17	Function Call
MPI_Comm_rank	test.c	20	Function Call
MPI_COMM_WORLD	test.c	20	Constant
MPI_Comm_size	test.c	23	Function Call
MPI_COMM_WORLD	test.c	23	Constant
MPI_Send	test.c	31	Function Call
MPI_CHAR	test.c	31	Constant
MPI_COMM_WORLD	test.c	32	Constant
MPI_Recv	test.c	37	Function Call
MPI_CHAR	test.c	37	Constant
MPI_COMM_WORLD	test.c	38	Constant

Make - test.c - Eclipse SDK
File Edit Refactor Navigate Search Project Run MPI Artifacts Window Help
Make Projects
Navigator
MyMakeProj
Binaries
Includes
Debug
test.c
MyProjCPP
MyProjNotIndexed
Help
Problems Console Properties MPI Artifact View
Writable
Smart Insert

Application Execution

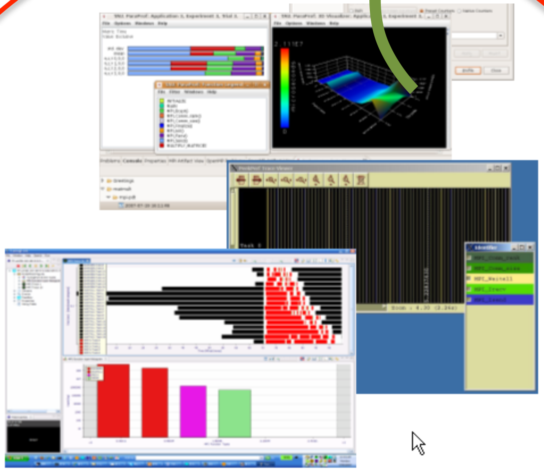

System Monitoring - Eclipse SDK
Monitors
Active Jobs
Inactive Jobs
Console
No consoles to display at this time.
system: login1.ls4.tacc.utexas.edu

Application Debugging



```
{
    int         my_rank;        /* rank of process */
    int         num_procs;      /* number of processes */
    int         source;         /* rank of sender */
    int         dest = 0;       /* rank of receiver */
    int         tag = 0;        /* tag for messages */
    char        message[100];   /* storage for message */
    MPI_Status  status ;        /* return status for receive */

    /* start up MPI */

    MPI_Init(&argc, &argv);

    /* find out process rank */
    MPI_Comm_rank(MPI_COMM_WORLD, &my_rank);
```

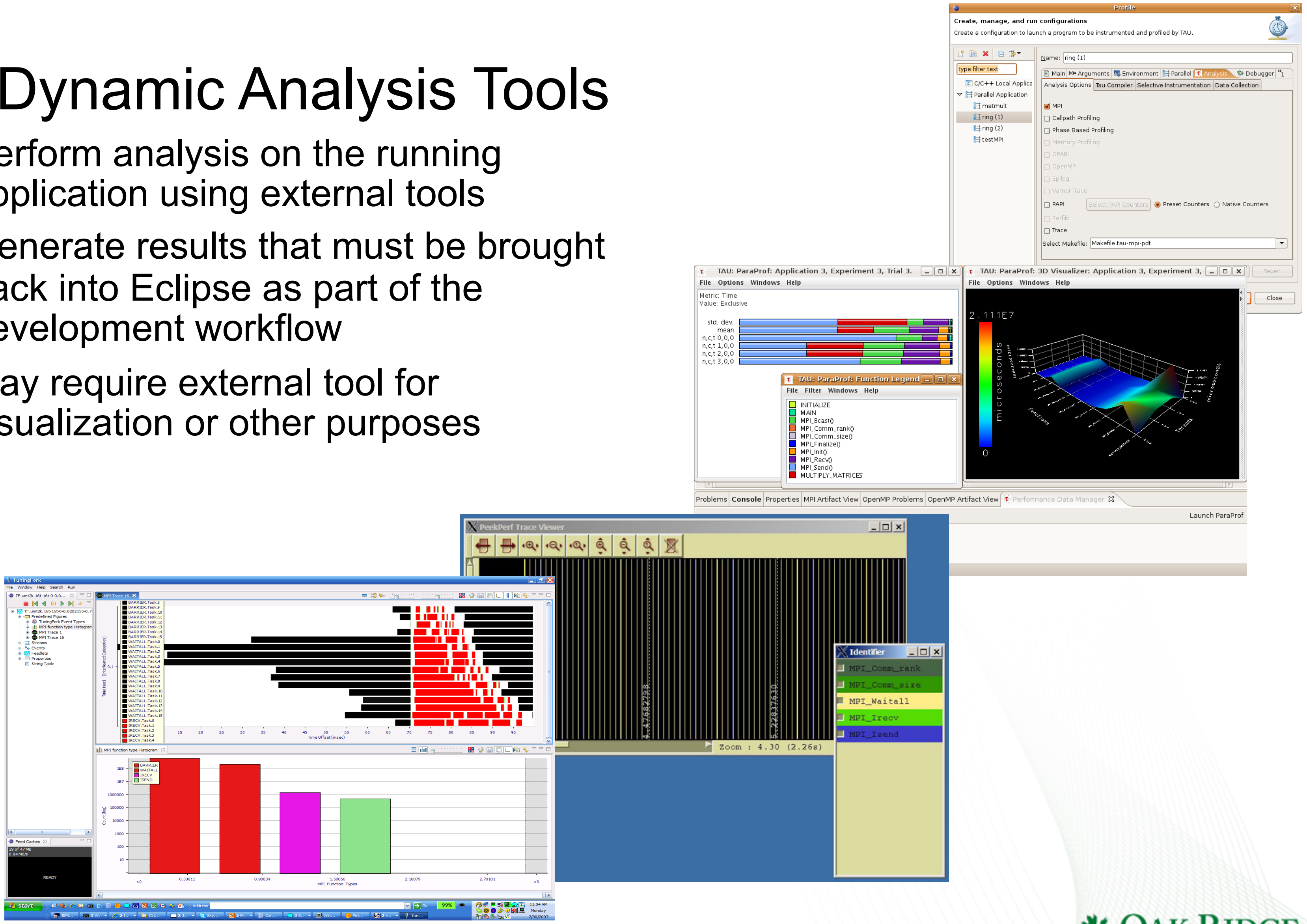
Name	Value
my_rank	4545765
num_procs	134515657
source	-1076822980
dest	-1076823128



Dynamic & Performance Analysis

Dynamic & Performance Analysis

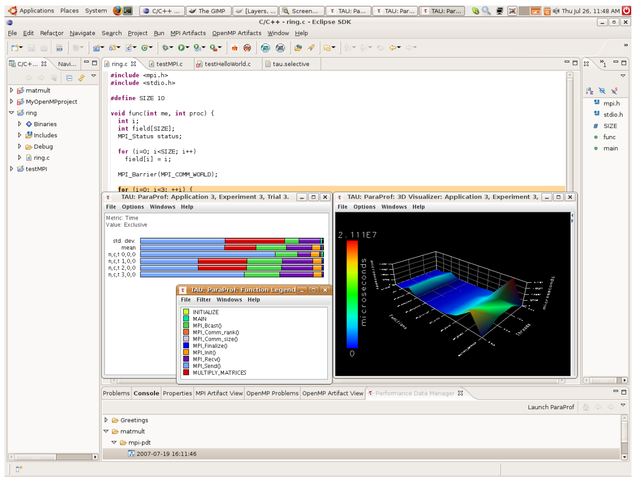
- Dynamic Analysis Tools
  - Perform analysis on the running application using external tools
  - Generate results that must be brought back into Eclipse as part of the development workflow
  - May require external tool for visualization or other purposes



Profile
Create, manage, and run configurations
Create a configuration to launch a program to be instrumented and profiled by TAU.
Name: ring (1)
Main | Arguments | Environment | Parallel | Analysis | Debugger
Analysis Options | Tau Compiler | Selective Instrumentation | Data Collection
MPI
Callpath Profiling
Phase Based Profiling
PAPI
Trace
Select Makefile: Makefile.tau-mpi-pdt
TAU: ParaProf: Application 3, Experiment 3, Trial 3.
Metric: Time
Value: Exclusive
TAU: ParaProf: 3D Visualizer: Application 3, Experiment 3,
TAU: ParaProf: Function Legend
INITIALIZE
MAIN
MPI_Bcast()
MPI_Comm_rank()
MPI_Comm_size()
MPI_Finalize()
MPI_Init()
MPI_Recv()
MPI_Send()
MULTIPLY_MATRICES
Problems | Console | Properties | MPI Artifact View | OpenMP Problems | OpenMP Artifact View | Performance Data Manager
Launch ParaProf
PeekPerf Trace Viewer
Zoom : 4.30 (2.26s)
Identifier
MPI_Comm_rank
MPI_Comm_size
MPI_Waitall
MPI_Irecv
MPI_Isend
TuningFork
MPI Trace 16
MPI function type Histogram
BARRIER
WAITALL
IRECV
ISEND
MPI Function Types

Dynamic & Performance Analysis

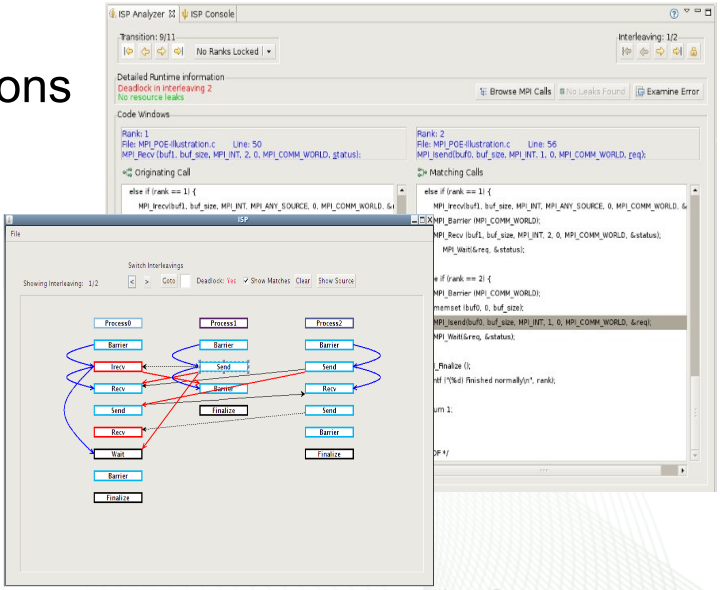
- Tuning and Analysis Utilities (TAU)
  - Instrumentation and transparent re-build of application executable
  - Execution of profiled application and collect performance data
  - Performance data visible in UI
  - Launches paraprof visualization client from Eclipse


C/C++ - ring.c - Eclipse SDK
ring.c
testMPI.c
testHelloWorld.c
tau.selective
TAU: ParaProf: Application 3, Experiment 3, Trial 3.
TAU: ParaProf: 3D Visualizer: Application 3, Experiment 3,
TAU: ParaProf: Function Legend
Launch ParaProf

```
#include <mpi.h>
#include <stdio.h>

#define SIZE 10

void func(int me, int proc) {
  int i;
  int field[SIZE];
  MPI_Status status;

  for (i=0; i<SIZE; i++)
    field[i] = i;

  MPI_Barrier(MPI_COMM_WORLD);

  for (i=0; i<3; ++i) {
```

Metric: Time
Value: Exclusive

- Graphical Explorer of MPI Programs (GEM)
  - Formal Dynamic Verification of MPI Applications
  - Detects all deadlocks, assert violations, MPI object leaks, and default safety properties
  - Matches sends and receives
  - Allows post-verification review of highlighted bugs
  - Works with a variety of MPI implementations



Detailed Runtime information
Deadlock in interleaving 2
No resource leaks

Code Windows

Rank: 1
File: MPI_POE-Illustration.c Line: 50
MPI_Recv (buf1, buf_size, MPI_INT, 2, 0, MPI_COMM_WORLD, status);

Rank: 2
File: MPI_POE-Illustration.c Line: 56
MPI_Isend(buf0, buf_size, MPI_INT, 1, 0, MPI_COMM_WORLD, req);

Deadlock: Yes

```
else if (rank == 1) {
    MPI_Irecv(buf1, buf_size, MPI_INT, MPI_ANY_SOURCE, 0, MPI_COMM_WORLD, &
    MPI_Barrier (MPI_COMM_WORLD);
    MPI_Recv (buf1, buf_size, MPI_INT, 2, 0, MPI_COMM_WORLD, &status);
      MPI_Wait(&req, &status);

e if (rank == 2) {
    MPI_Barrier (MPI_COMM_WORLD);
    memset (buf0, 0, buf_size);
    MPI_Isend(buf0, buf_size, MPI_INT, 1, 0, MPI_COMM_WORLD, &req);
    MPI_Wait(&req, &status);

I_Finalize ();
ntf ("(%d) Finished normally\n", rank);

urn 1;

DF */
```

Online Information

- **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

Community

- **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 - higher volume
    - http://dev.eclipse.org/mailman/listinfo/ptp-dev