INTERMITTENT MULTI-THREADING BUGS: FIND AND SQUASH RACES, DEADLOCKS, AND MEMORY BUGS

Memory & Thread Debugger

Here is What Will Be Covered

Overview

Memory/Thread analysis

New Features

Deep dive into debugger integrations

Demo

Call to action

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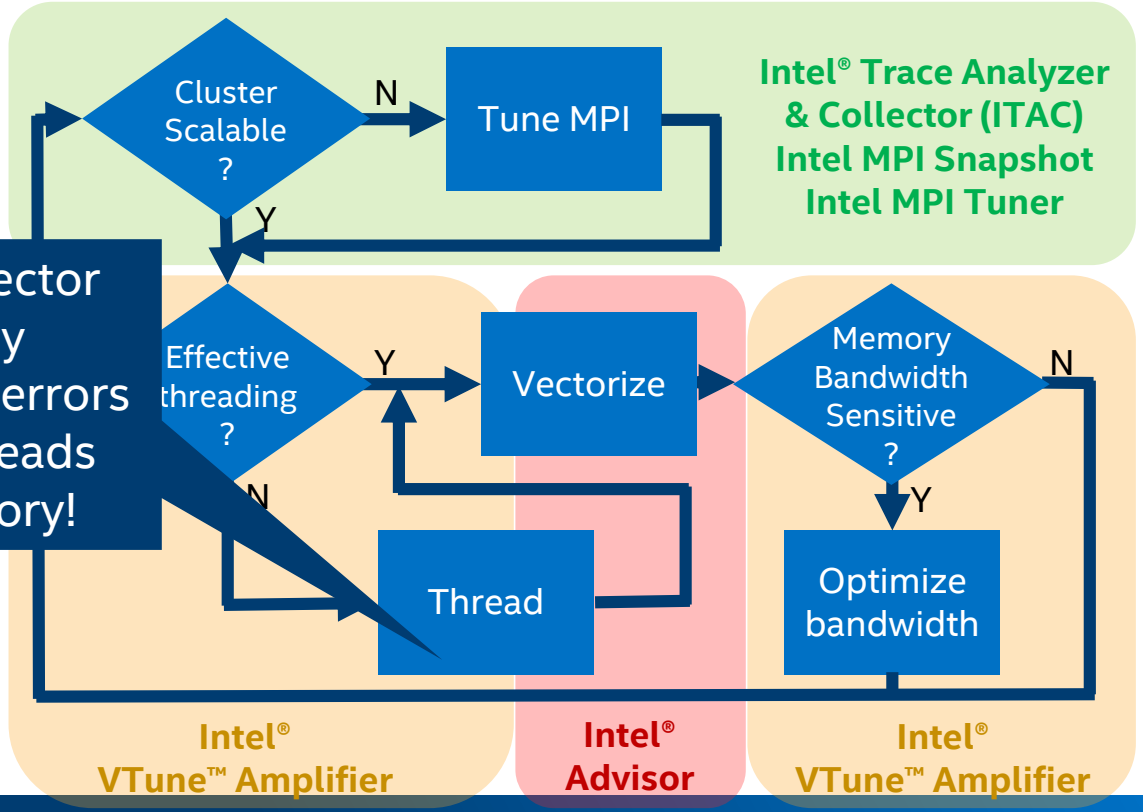
Analysis Tools for Diagnosis

Intel® Parallel Studio XE



Intel® Inspector
Find any correctness errors in your threads and memory!

Intel® Parallel Studio XE

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Correctness Tools Increase ROI By 12%-21%

Cost Factors – Square Project Analysis

CERT: U.S. Computer Emergency Readiness Team, and Carnegie Mellon CyLab

NIST: National Institute of Standards & Technology : Square Project Results

Size and complexity of applications is growing

Reworking defects is 40%-50% of total project effort

Correctness tools find defects during development prior to shipment

Reduce time, effort, and cost to repair

Find errors earlier when they are less expensive to fix

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Find & Debug Memory & Threading Errors

Intel® Inspector – Memory & Thread Debugger

Correctness Tools Increase ROI By 12%-21%[1]

- Errors found earlier are less expensive to fix
- Several studies, ROI% varies, but earlier is cheaper

Diagnosing Some Errors Can Take Months

- Races & deadlocks not easily reproduced
- Memory errors can be hard to find without a tool

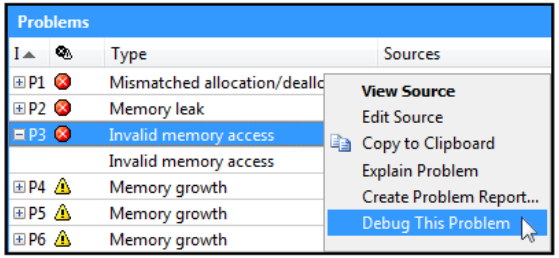
Debugger Integration Speeds Diagnosis

- Breakpoint set just before the problem
- Examine variables & threads with the debugger

Diagnose in hours instead of months

[1] **Cost Factors – Square Project Analysis**
CERT: U.S. Computer Emergency Readiness Team, and Carnegie Mellon CyLab
NIST: National Institute of Standards & Technology : Square Project Results

Debugger Breakpoints



Part of Intel® Parallel Studio
For Windows* and Linux*

Intel® Inspector dramatically sped up our ability to track down difficult to isolate threading errors before our packages are released to the field.

Peter von Kaenel, Director, Software Development, ***Harmonic Inc.***

http://intel.ly/inspector-xe

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Debug Memory & Threading Errors

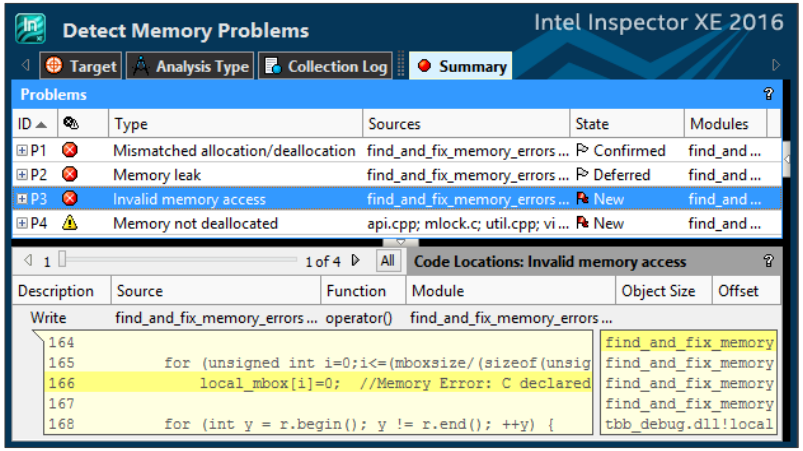
Intel® Inspector

Find and eliminate errors

- Memory leaks, invalid access…
- Races & deadlocks
- C, C++, C#, F# and Fortran (or a mix)

Simple, Reliable, Accurate

- No special recompiles
  Use any build, any compiler[1]
- Analyzes dynamically generated or linked code
- Inspects 3rd party libraries without source
- Productive user interface + debugger integration
- Command line for automated regression analysis



Clicking an error instantly displays source code snippets and the call stack

Fits your existing process

[1]That follows common OS standards.
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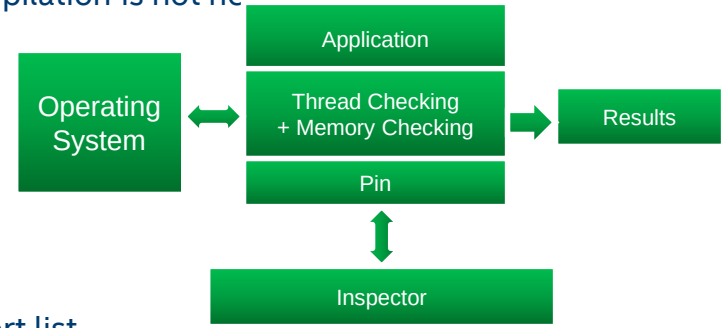
Intel® Inspector dynamic analysis

Data Collection Techniques

Inspector tracks all memory allocations and threading APIs using a binary instrumentation tool called Pin

- Dynamic instrumentation system provided by Intel (http://www.pintool.org)
- Injected code used for observing the behaviour of the program
- Source modification/recompilation is not needed



- OS has to be in the support list
- One process is analysed at a time

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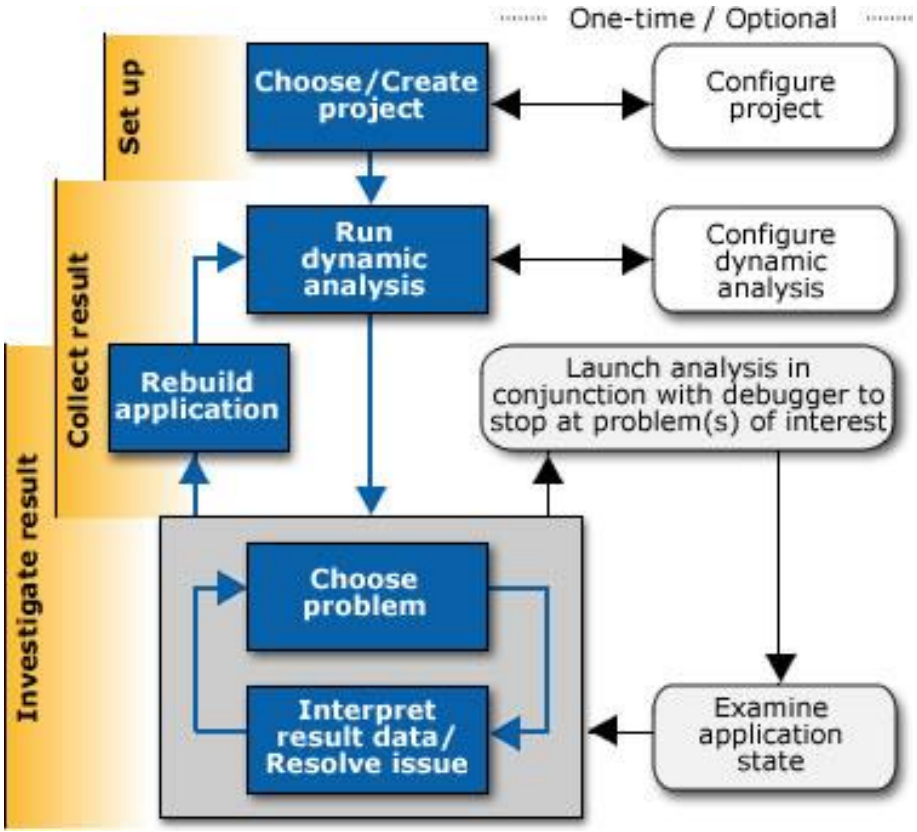
Recommended Methodology



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Race Conditions Are Difficult to Diagnose

They only occur occasionally and are difficult to reproduce

Correct

Thread 1	Thread 2		Shared Counter
			0
Read count		←	0
Increment			0
Write count		→	1
	Read count	←	1
	Increment		1
	Write count	→	2

Incorrect

Thread 1	Thread 2		Shared Counter
			0
Read count		←	0
	Read count	←	0
Increment			0
	Increment		0
Write count		→	1
	Write count	→	1

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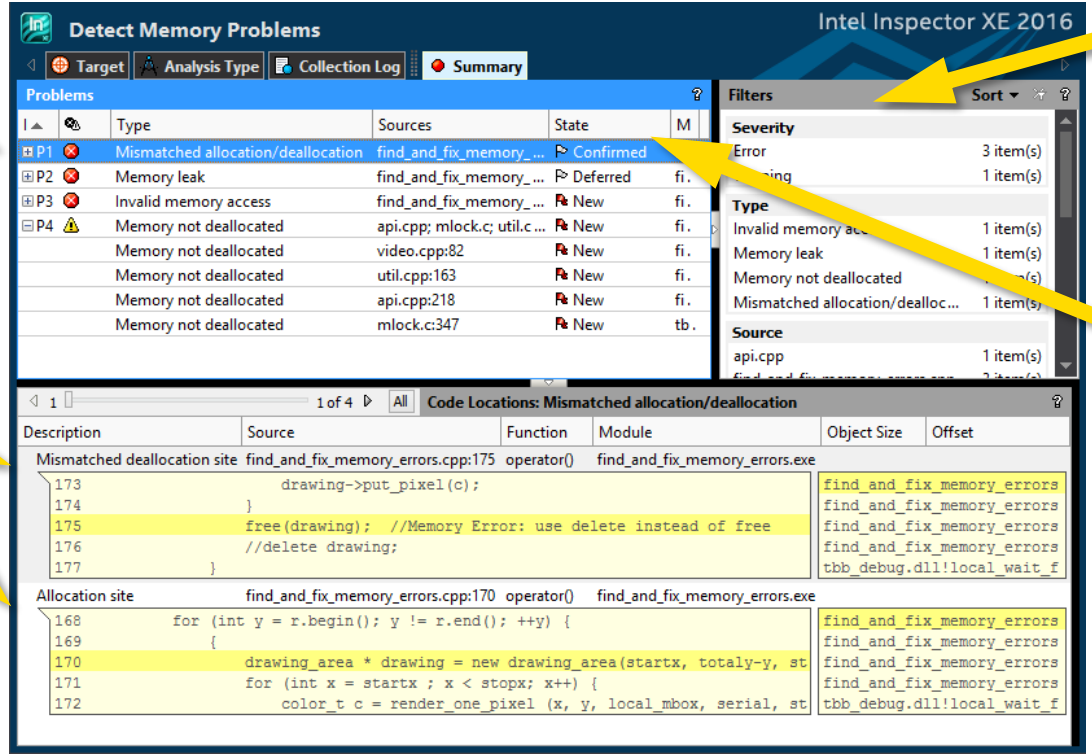
Productive User Interface Saves Time

Intel® Inspector

Select a **problem set**

Code snippets displayed for selected problem



Filters let you focus on a module, or error type, or just the new errors or…

Problem States: New, Not Fixed, Fixed, Confirmed, Not a problem, Deferred, Regression

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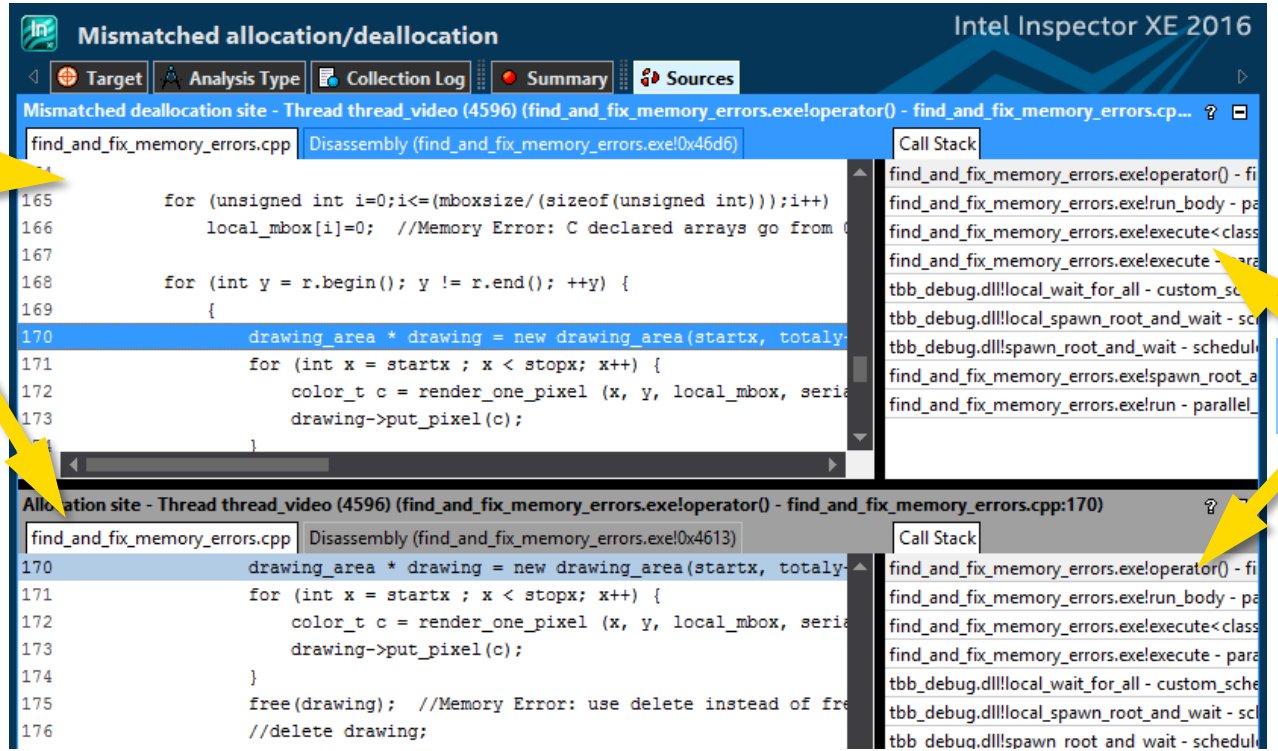
Double Click for Source & Call Stack

Intel® Inspector

Source code locations displayed for selected problem



Call Stack

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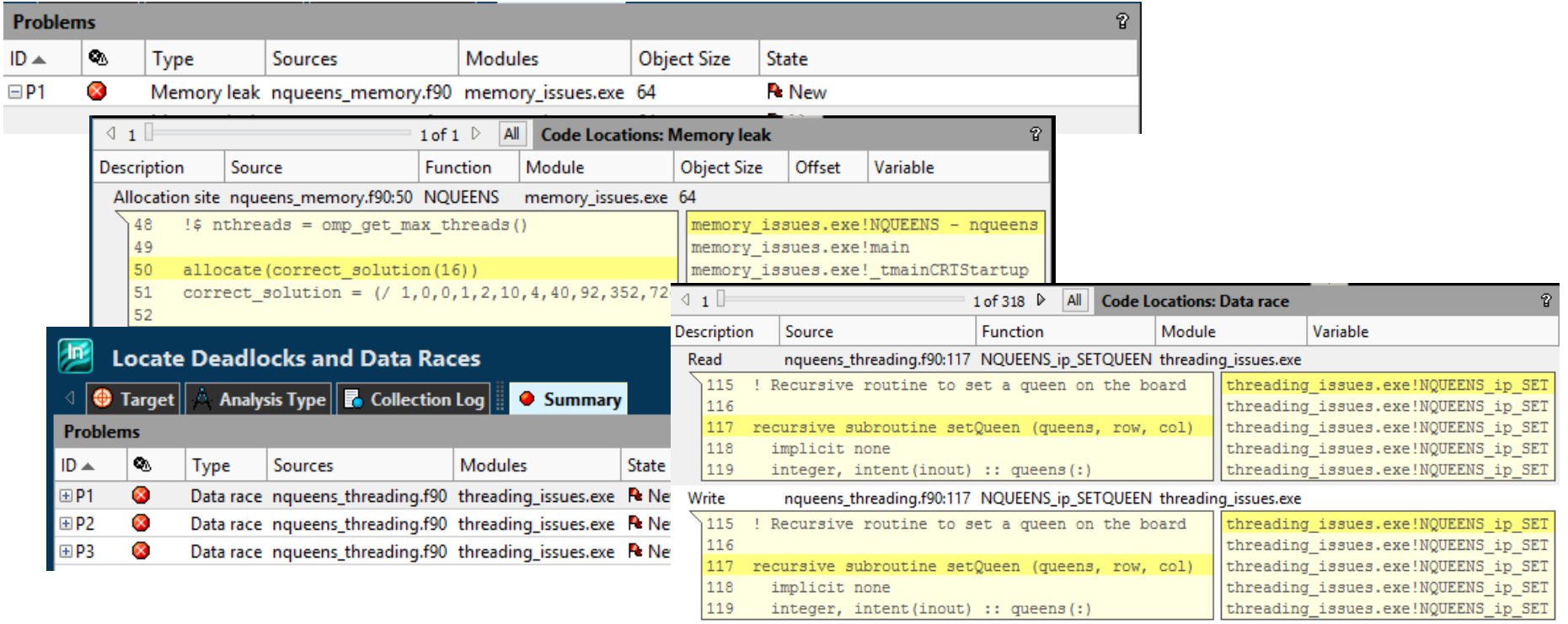
Quickly track down your Fortran issues!



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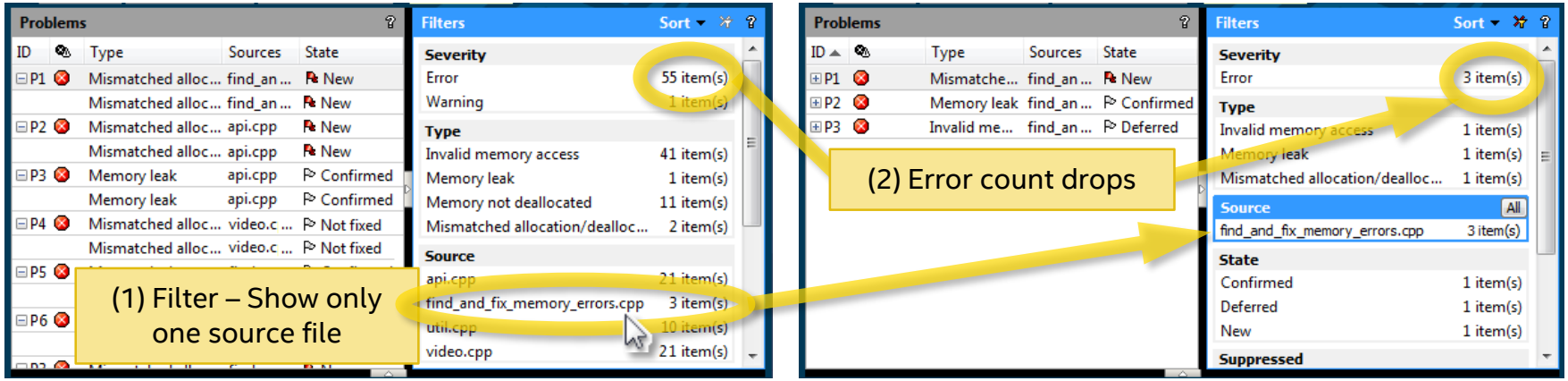
Filtering - Focus on What's Important

Example: See only the errors in one source file

Before – All Errors

After – Only errors from one source file



Tip: Set the "Investigated" filter to "Not investigated" while investigating problems.
This removes from view the problems you are done with, leaving only the ones left to investigate.

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Incrementally Diagnose Memory Growth

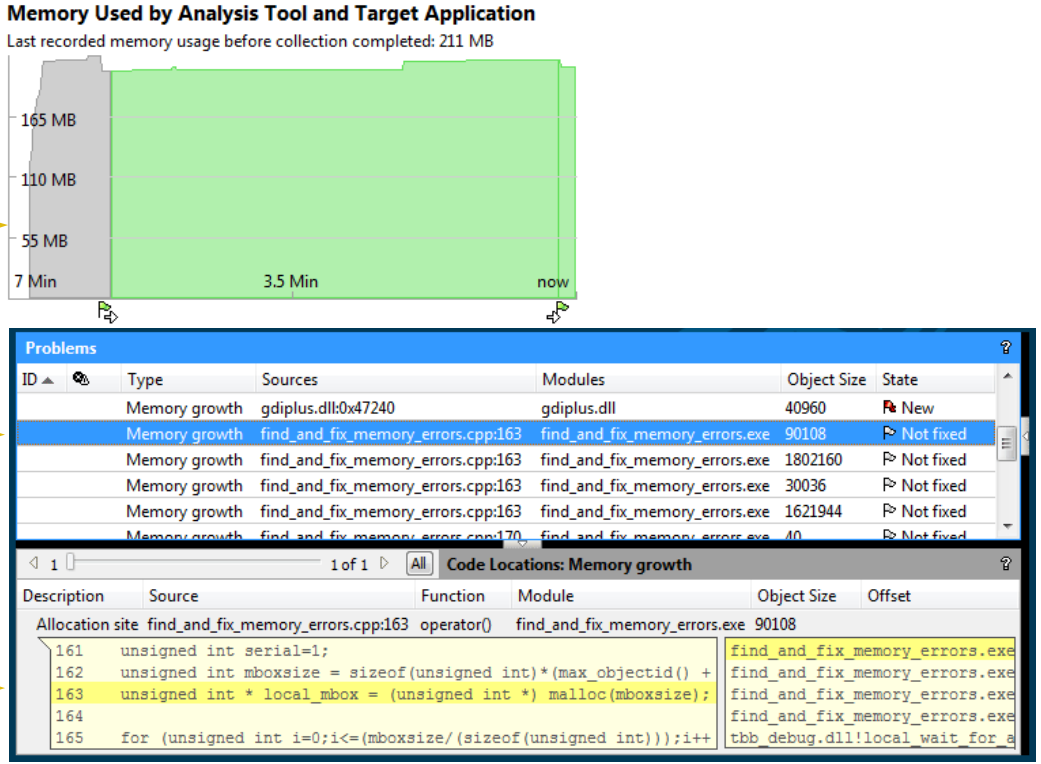
Intel® Inspector

As your app is running…

Memory usage graph plots memory growth

Select a cause of memory growth

See the code snippet & call stack



Speed diagnosis of difficult to find heap errors

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Automate Regression Analysis

Command Line Interface

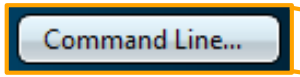
inspxe-cl is the command line:

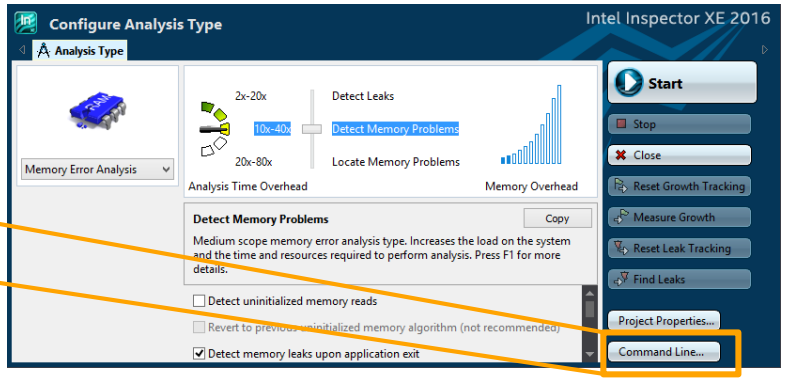
- **Windows:** `C:\Program Files\Intel\Inspector XE \bin[32|64]\inspxe-cl.exe`
- **Linux:** `/opt/intel/inspector_xe/bin[32|64]/inspxe-cl`

Help:

```
inspxe-cl -help
```

Set up command line with GUI





Command examples:

1. `inspxe-cl -collect-list`
2. `inspxe-cl -collect ti2 -- MyApp.exe`
3. `inspxe-cl -report problems`

Send results file to developer to analyze with the UI

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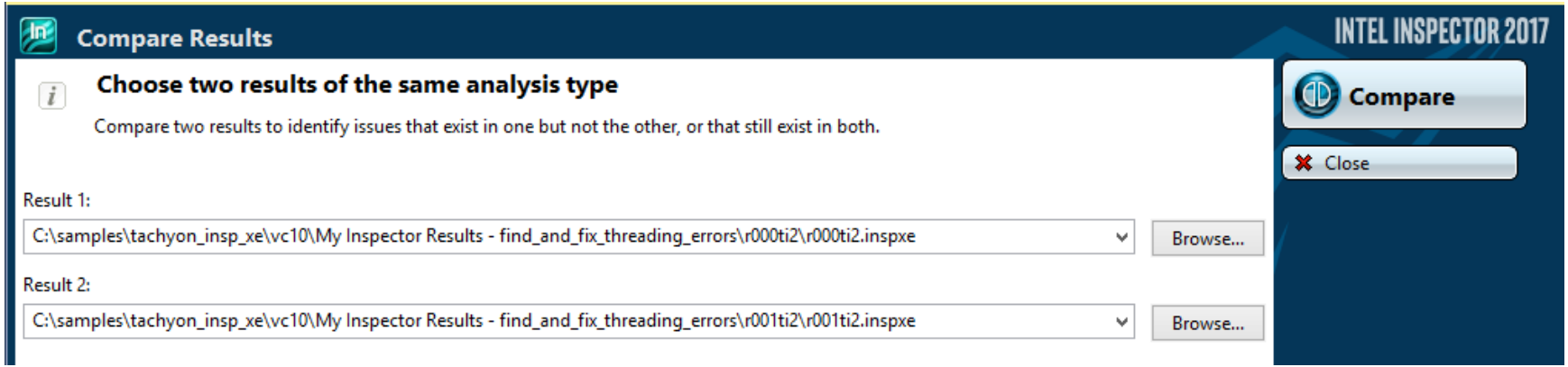
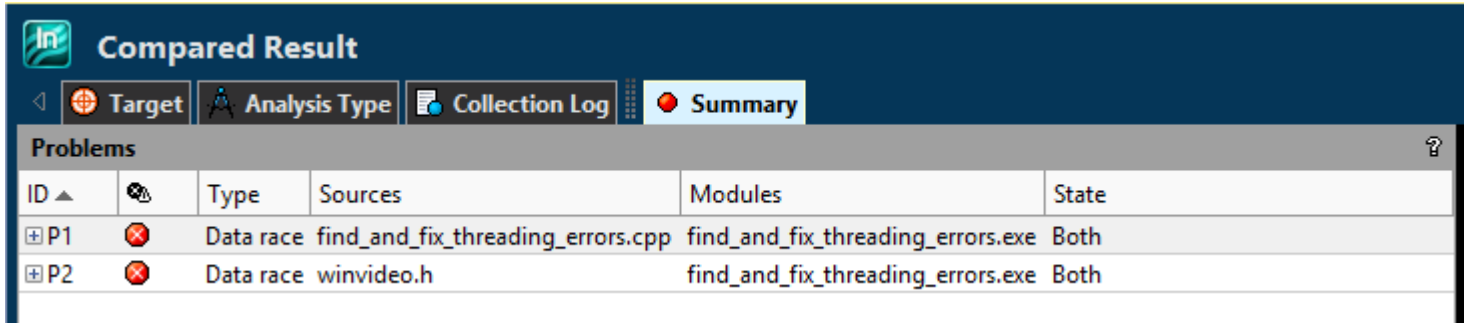
Compare results and see what has changed

Ideal for regression testing





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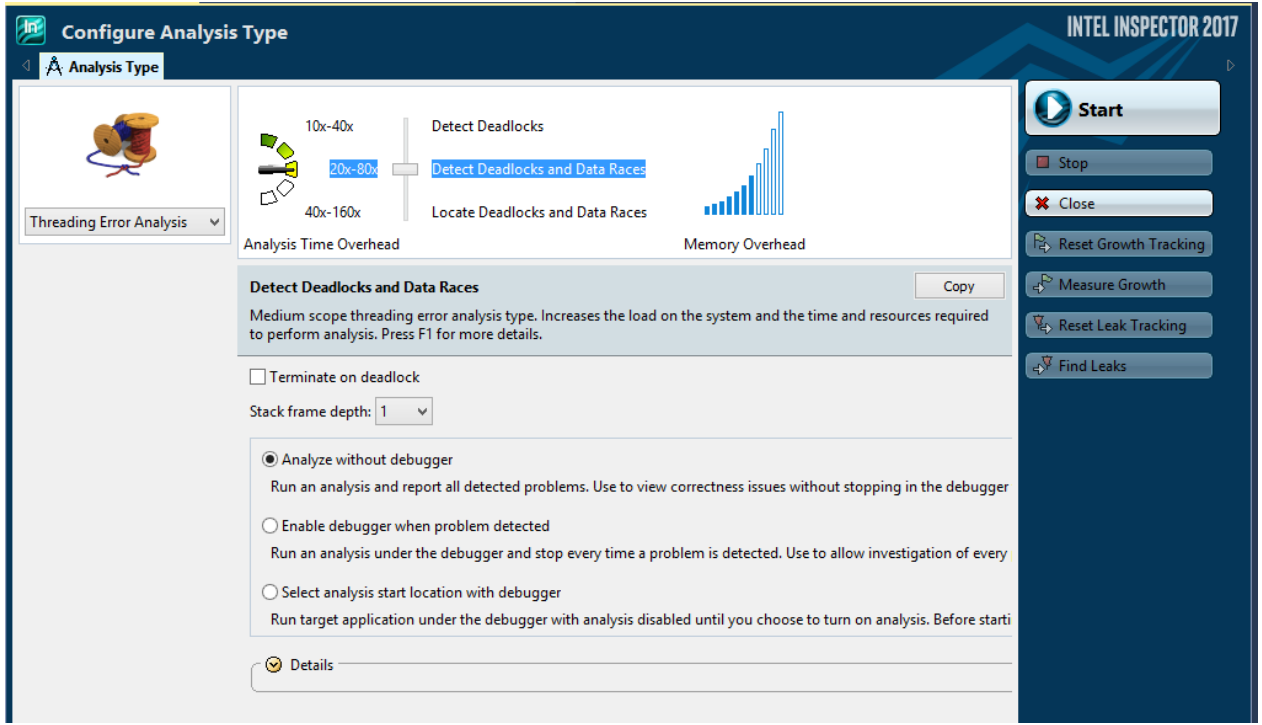
Find problems quicker!

Interactive debugging support



3 debugging modes supported

1. Analyze without debugger
2. Enable debugger when problem detected
3. Start analysis when a debug breakpoint is hit.

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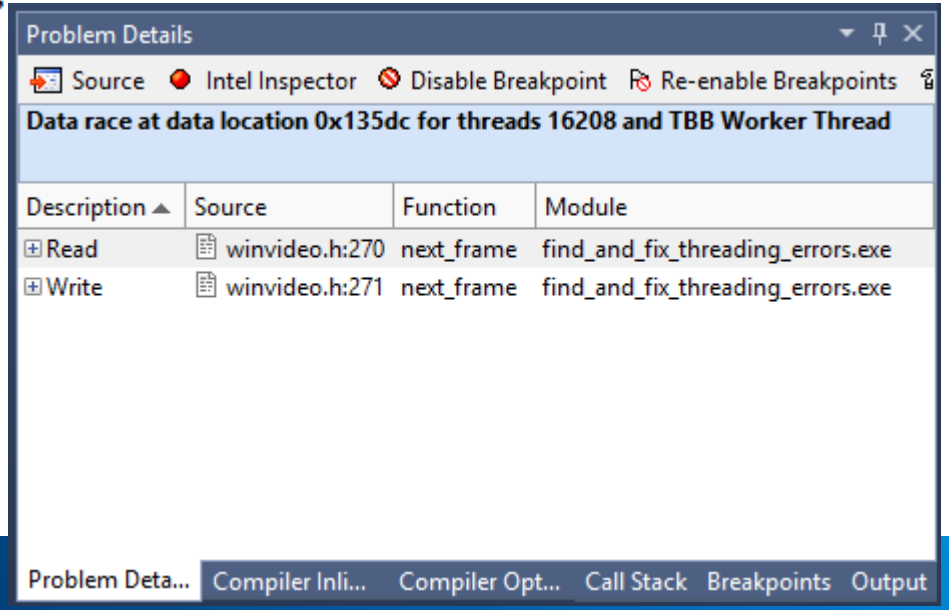
Intuitive problem solving using debugger integrations

```
//! Refresh screen picture
bool video::next_frame()
{
    if(!running) return false;
    g_updates++; // Fast but inaccurate counter. The data race here is beni
    if(!threaded) while(loop_once(this));
    else if(g_handles[1]) {
        SetEvent(g_handles[1]);
        YIELD_TO_THREAD();
    }
    return true;
}
```

Microsoft Visual Studio* and GNU gdb* or Intel® Debugger (on Linux*)



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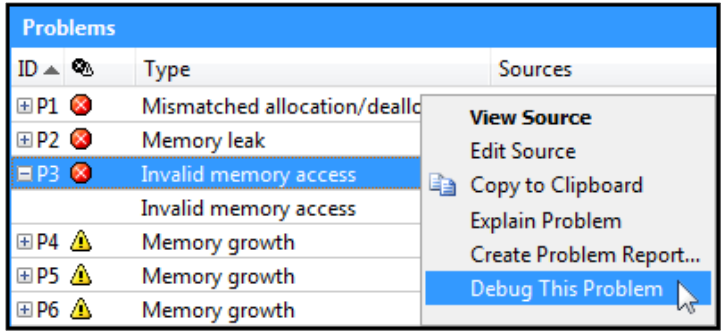
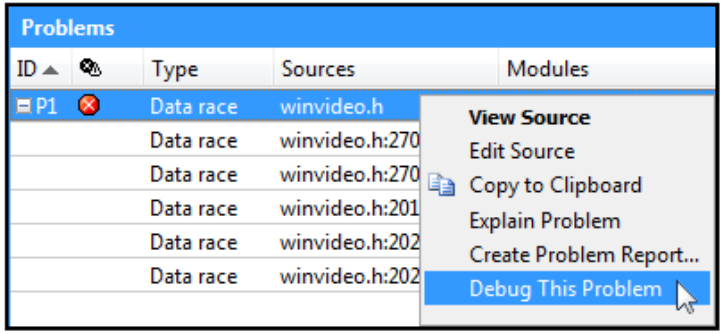
Break At Just The Right Time

Intel® Inspector - Memory & Thread Debugger

Memory Errors



Threading Errors



Break into the debugger just before the error occurs.

Examine the variables and threads.

Diagnose the problem.

Save time. Find and diagnose errors with less effort.

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Work Smarter & Faster

Intel® Inspector - Memory & Thread Debugger

Precise Error Suppression

```
Suppression = {
    Name = "Example";
    Type = { uninitialized_memory_access }
    Stacks = {
        {
            mod=a.out, func=update_x;
            func=main;
```

Precise, easy to edit, team shareable.

Choose which stack frame to suppress.

Eliminate the false, not the real errors.

Pause/Resume Collection

```
__itt_suppress_push(__itt_suppress_threading_errors);
    /* Any threading errors here are ignored */
__itt_suppress_pop();
    /* Any threading errors here are seen */
```

Speed-up analysis by limiting its scope.

Analyze only during the execution of the suspected problem.

Find and diagnose errors with less effort.

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Productive Memory & Threading Debugger

Intel® Inspector

	Memory Analysis	Threading Analysis
View Context of Problem		
Stack	✓	✓
Multiple Contributing Source Locations	✓	✓
Collapse multiple “sightings” to one error (e.g., memory allocated in a loop, then leaked is 1 error)	✓	✓
Suppression, Filtering, and Workflow Management	✓	✓
Visual Studio* Integration (Windows*)	✓	✓
Command line for automated tests	✓	✓
Time Line visualization	✓	✓
Memory Growth during a transaction	✓	
Trigger Debugger Breakpoint	✓	✓

Easier & Faster Debugging of Memory & Threading Errors

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WHAT'S NEW

New Features

Support for Intel® Xeon Phi™ processor (codename: Knights Landing)

Support for C++11 synchronization primitives during threading analysis

Variable name detection for threading analysis

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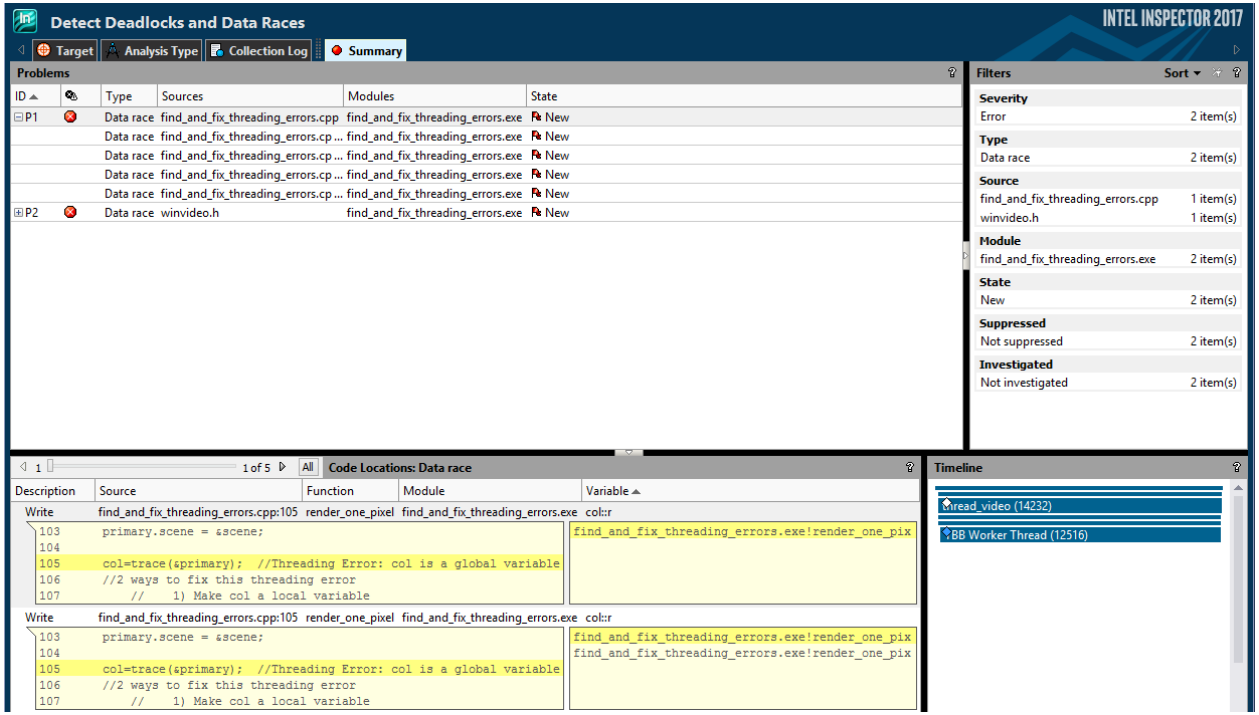
Variable name detection for threading analysis



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Memory & Threading Debugger Saves Time

Intel® Inspector

"We struggled for a week with a crash situation, the corruption was identified but the source was really hard to find. Then we ran **Intel® Inspector** and immediately found the array out of bounds that occurred long before the actual crash. We could have saved a week!"

Mikael Le Guerroué,
Senior Codec Architecture Engineer,
Envivio

"**Intel® Inspector** is quite fast and intuitive compared to products we have used in the past. We can now run our entire batch of test cases (~750) which was not feasible previously. **Intel® Inspector** easily completed tests that failed due to lack of virtual memory on another product."

Gerald Mattauch
Senior Software Developer
***Siemens AG**, Healthcare Sector*

Intel® Inspector has dramatically sped up our ability to find/fix memory problems and track down difficult to isolate threading errors before our packages are released to the field.

Peter von Kaenel, Director,
Software Development,
Harmonic Inc.

More Case Studies

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Call to Action

Modernize your Code

- To get the most out of your hardware, you need to modernize your code with vectorization and threading.
- Taking a methodical approach such as the one outlined in this presentation, and taking advantage of the powerful tools in Intel® Parallel Studio XE, can make the modernization task dramatically easier.

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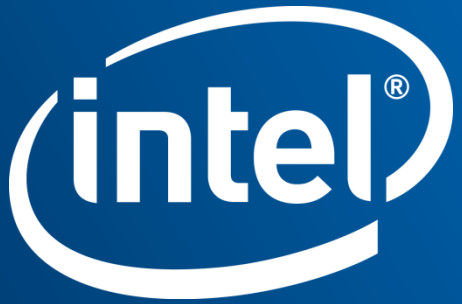
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