
# Intel® Inspector XE 2016

**Memory and thread debugger**

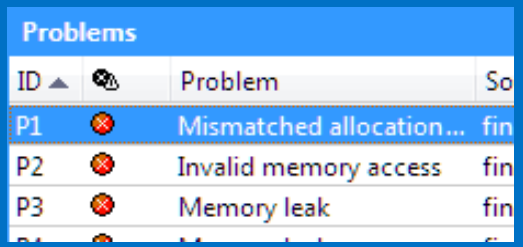
# Agenda

- Intro to Intel® Inspector XE
- Analysis workflow
- Memory problem analysis
- Threading problem Analysis
- Integration with debugger
- Automated regression testing and user API

# Intro to Intel® Inspector XE

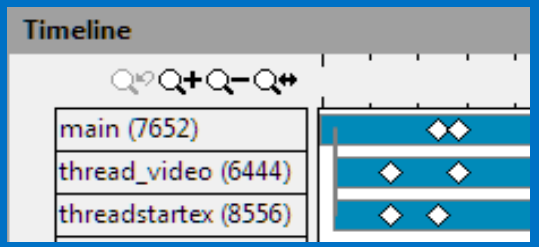
# Motivation for The Inspector XE

## Memory Errors




- Invalid Accesses
- Memory Leaks
- Uninitialized Memory Accesses

## Threading Errors



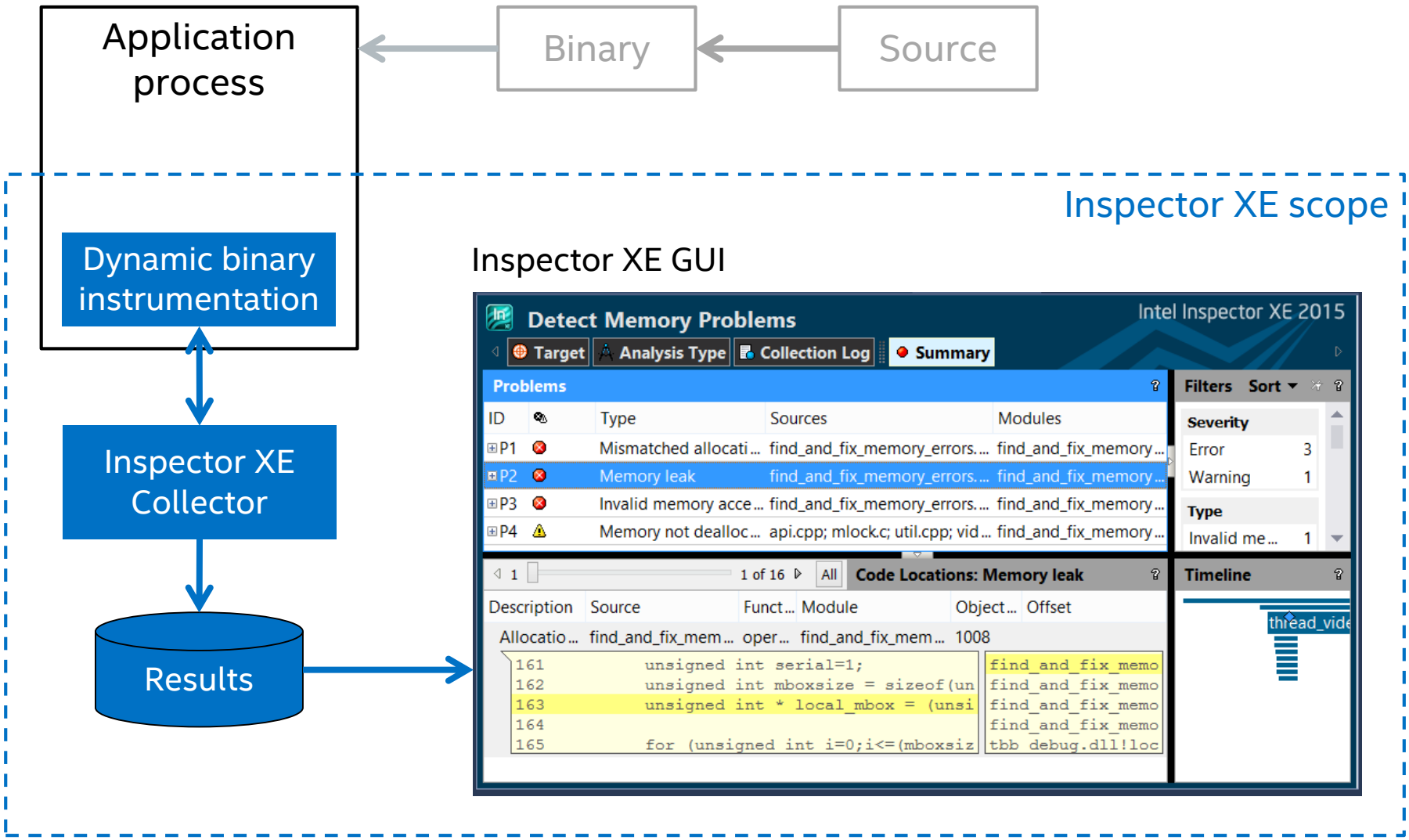

- Data Races
- Deadlocks
- Cross Stack References

## Multi-threading problems

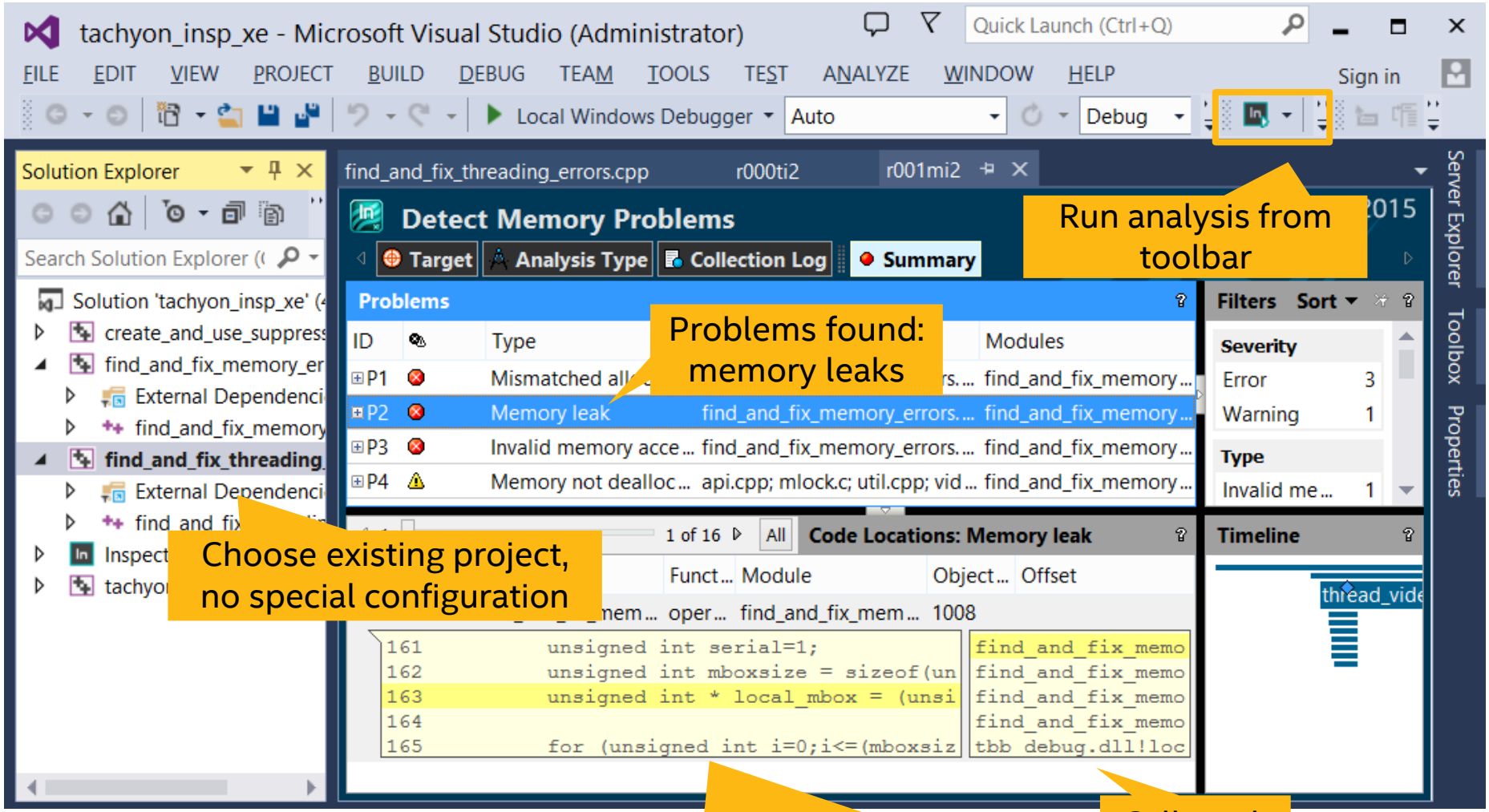
- Hard to reproduce,
- Difficult to debug
- Expensive to fix

→ Let the tool do it for you

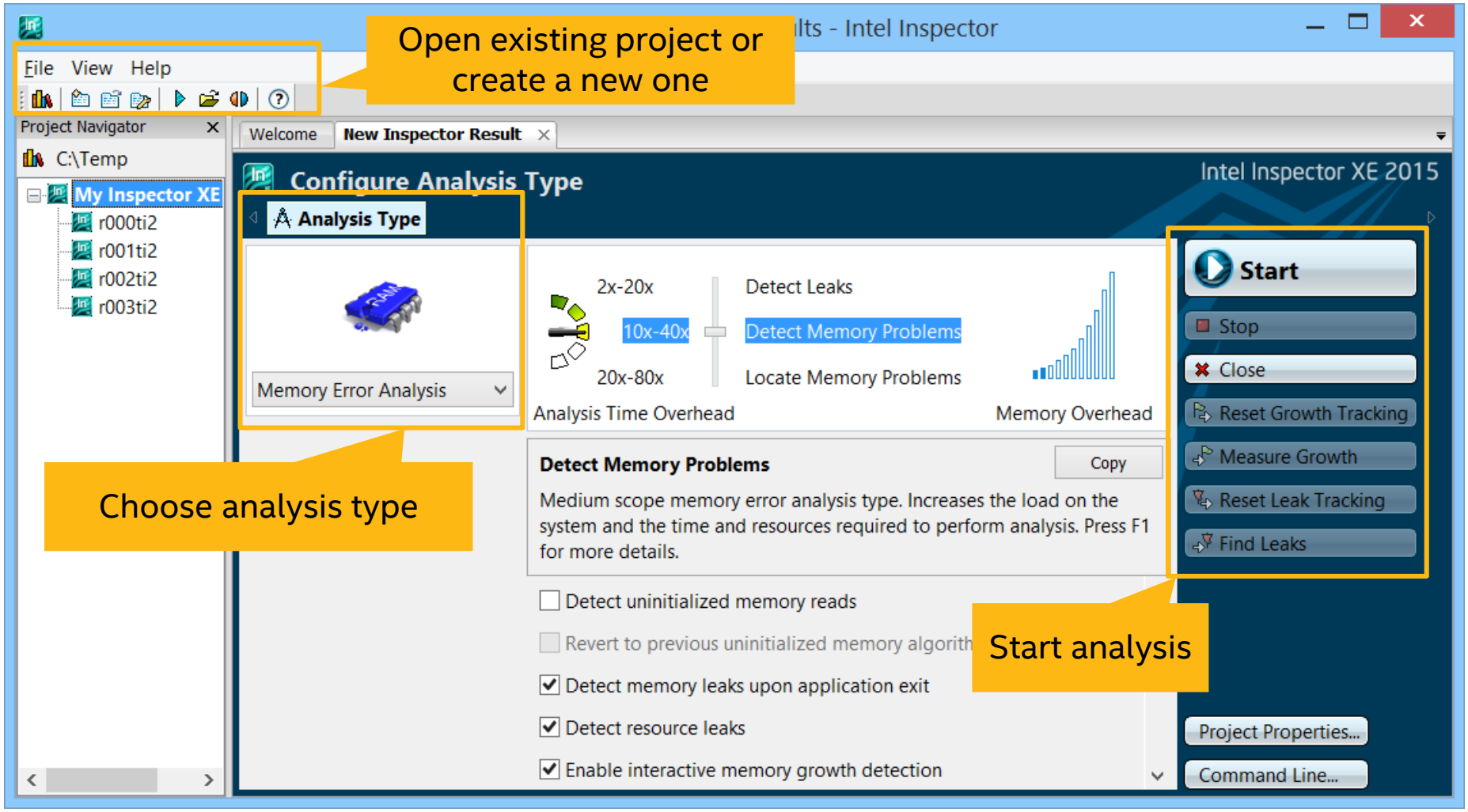
# Intel Inspector XE: Dynamic analysis



# How it looks: Visual Studio* Integration

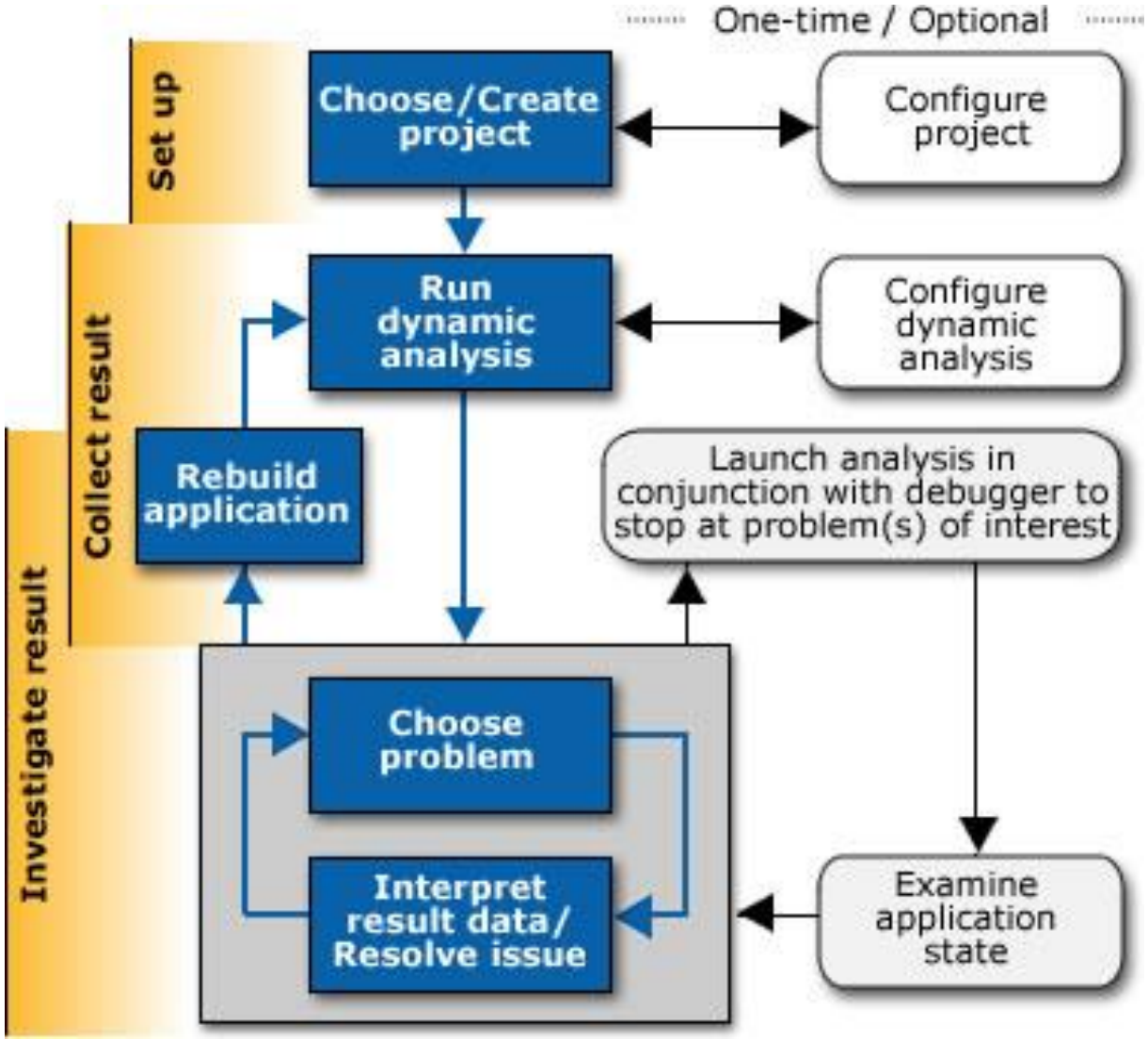


# Standalone GUI: Windows* and Linux*

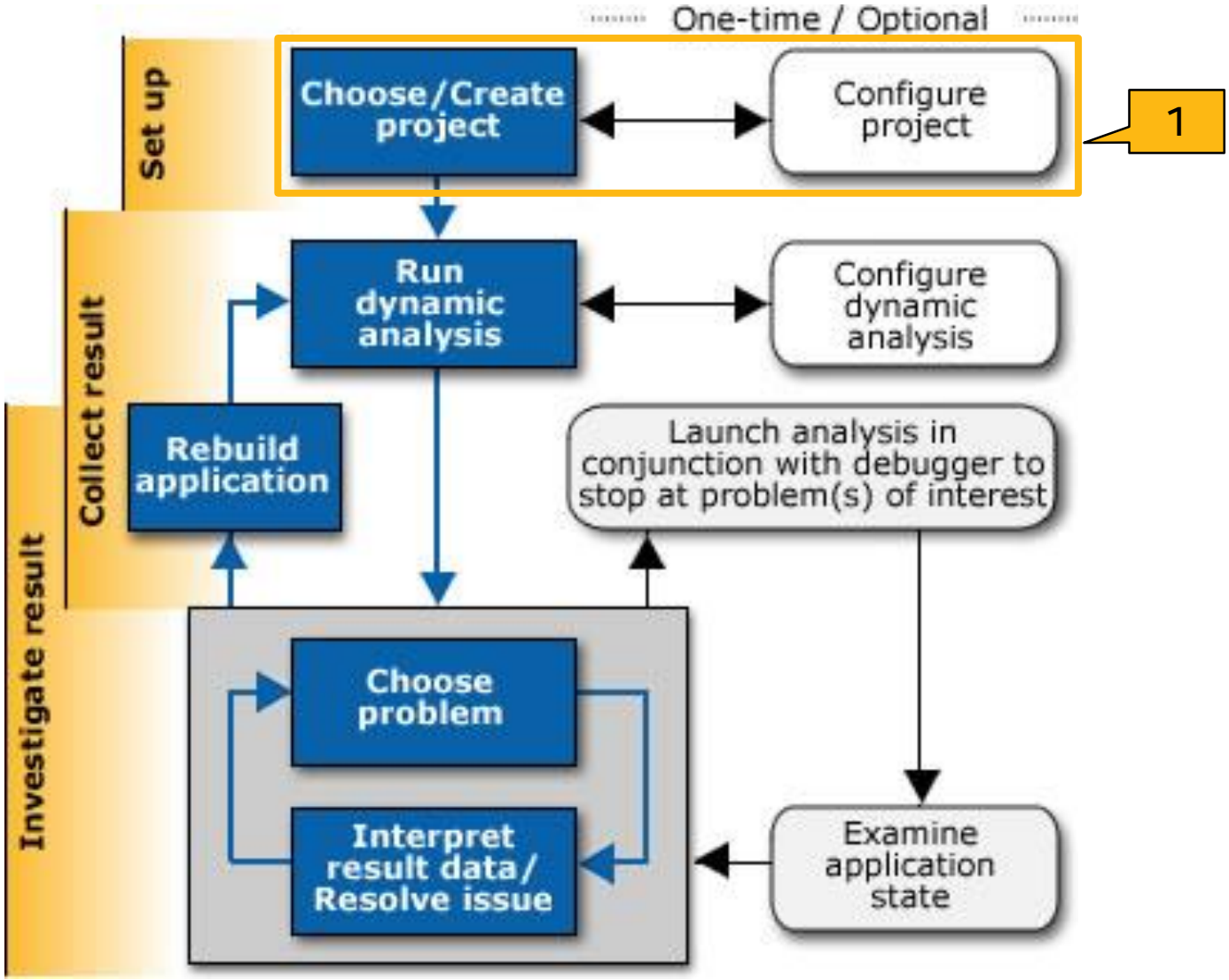


# Analysis workflow

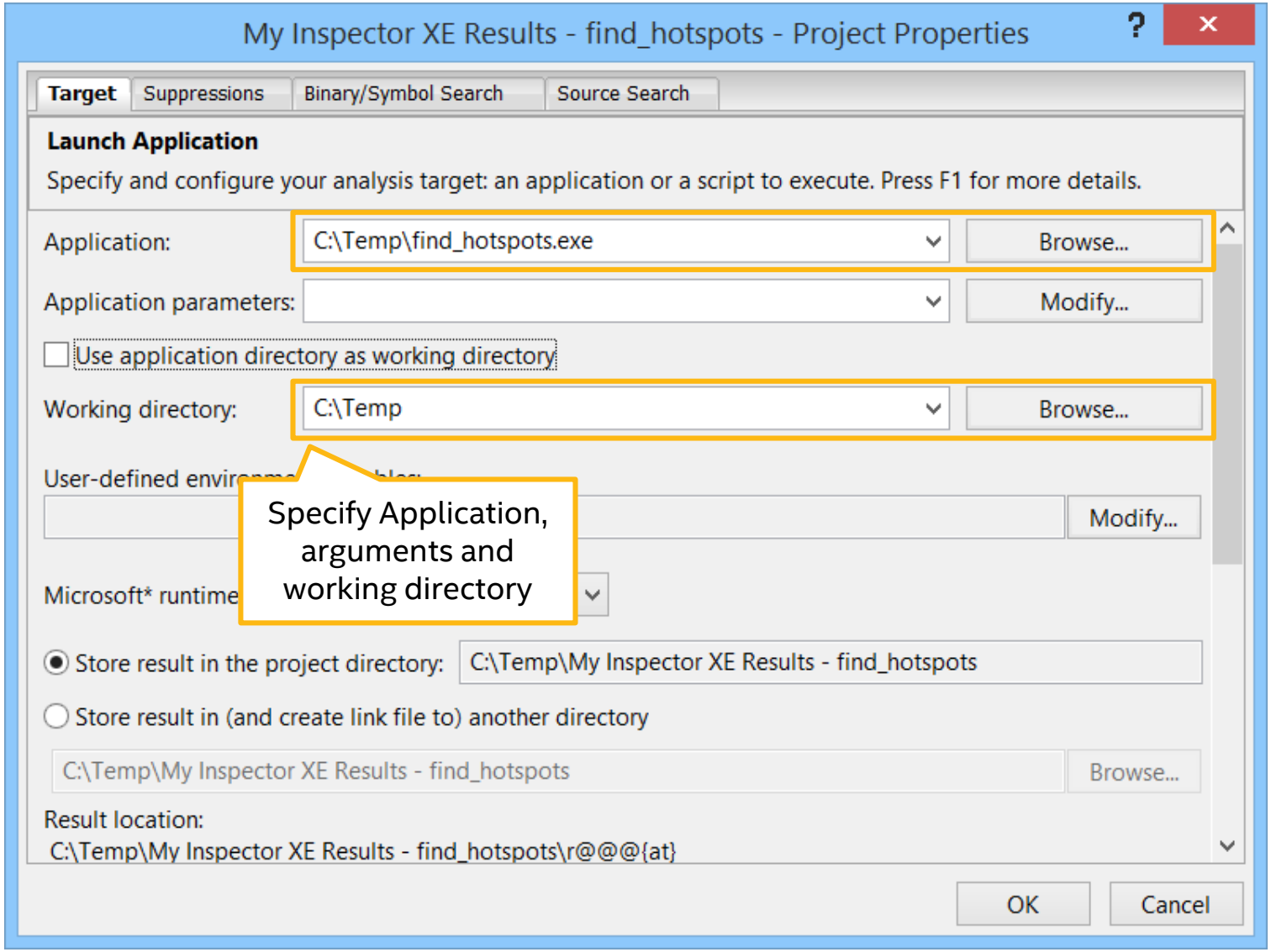
# Workflow: Dynamic Analysis



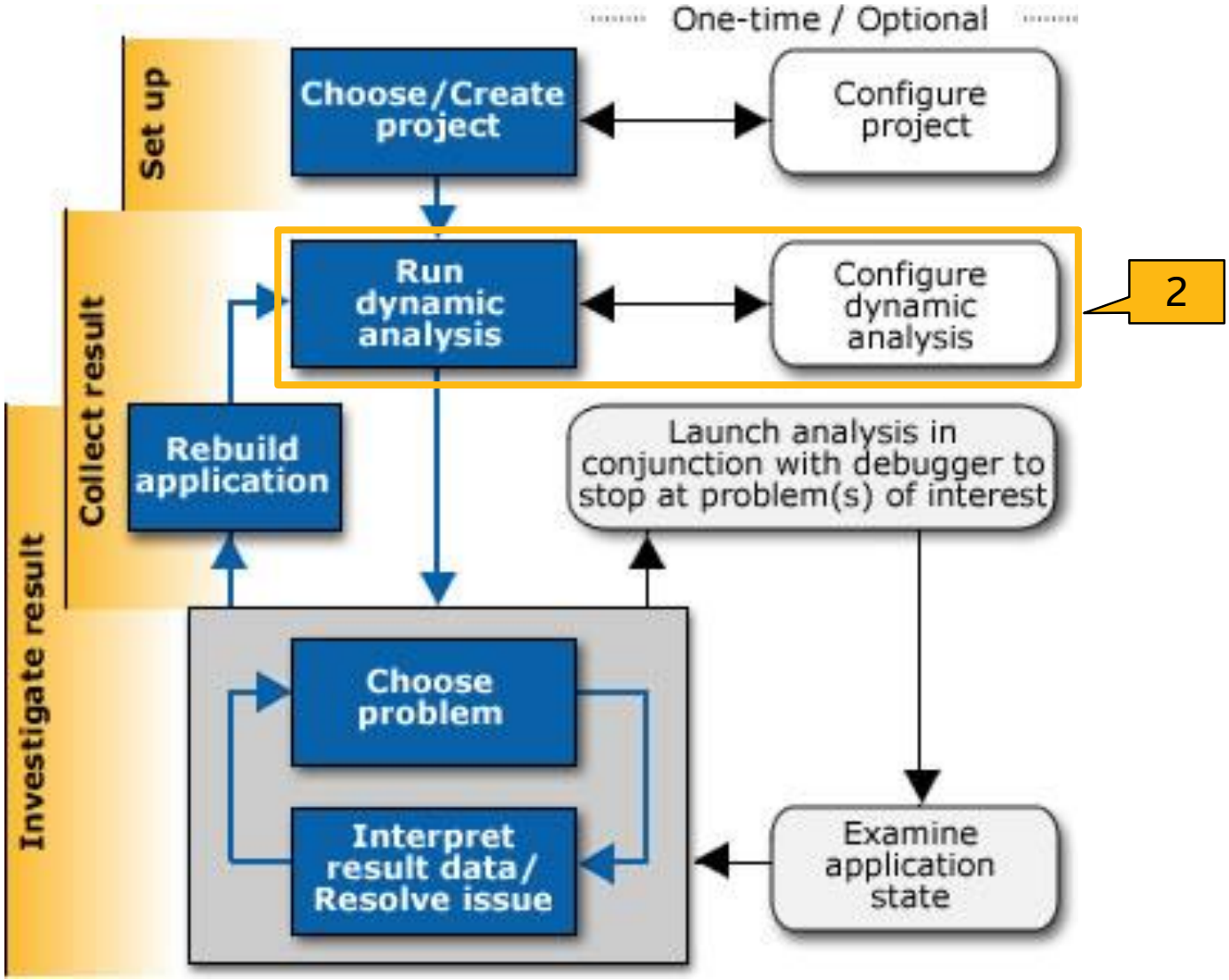
# Workflow: Dynamic Analysis



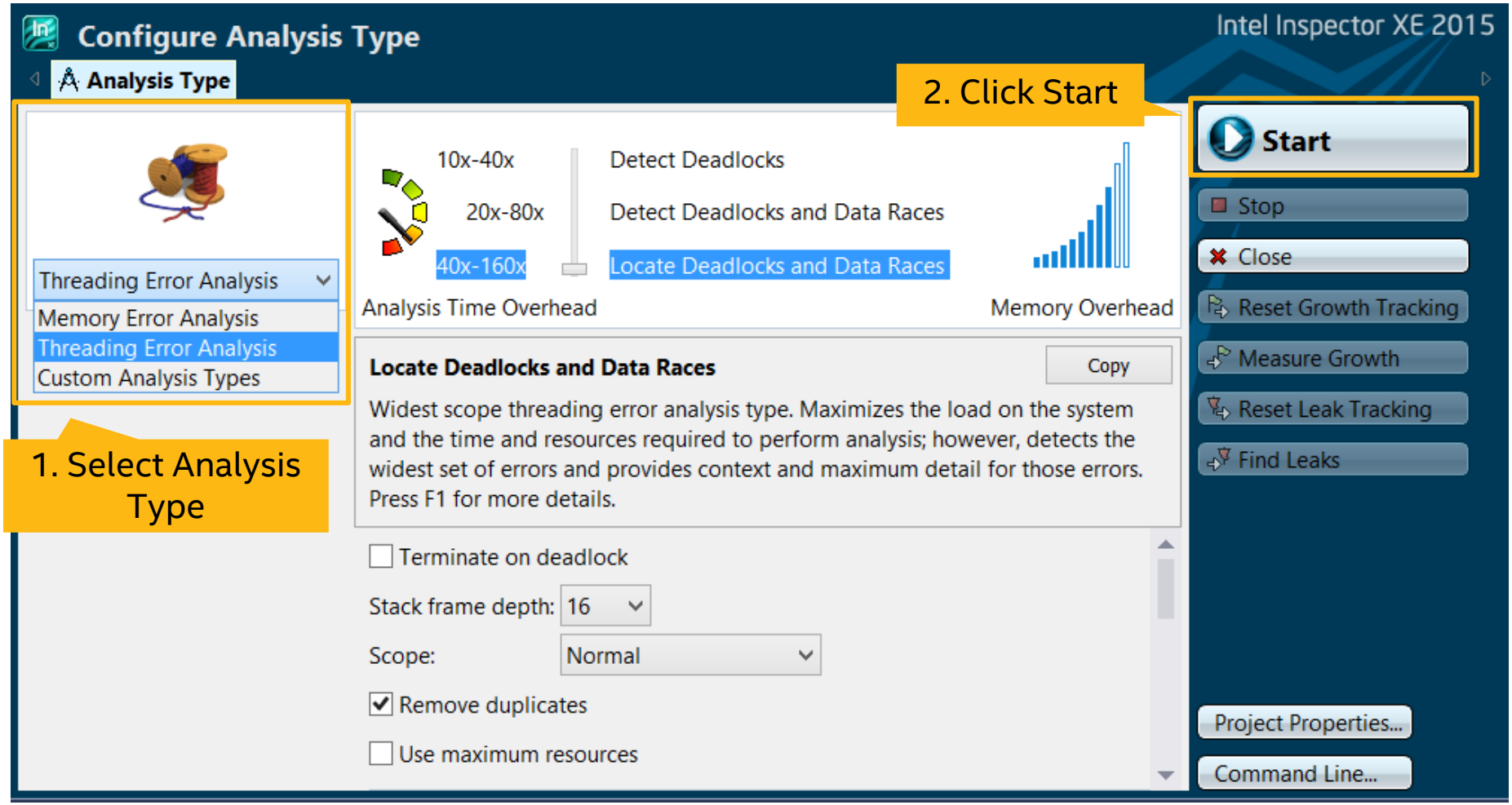
# Workflow: setup project



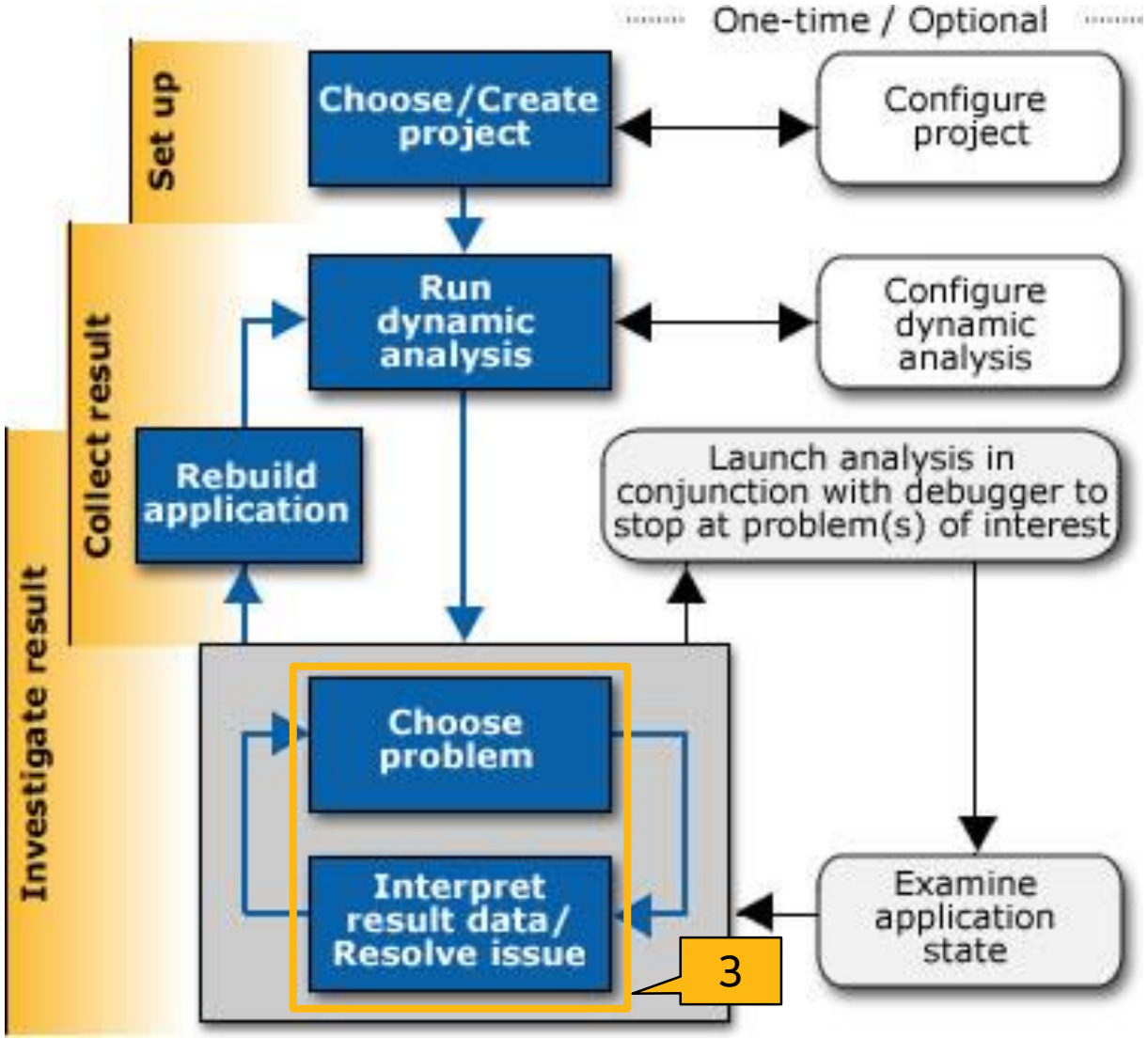
# Workflow: Dynamic Analysis



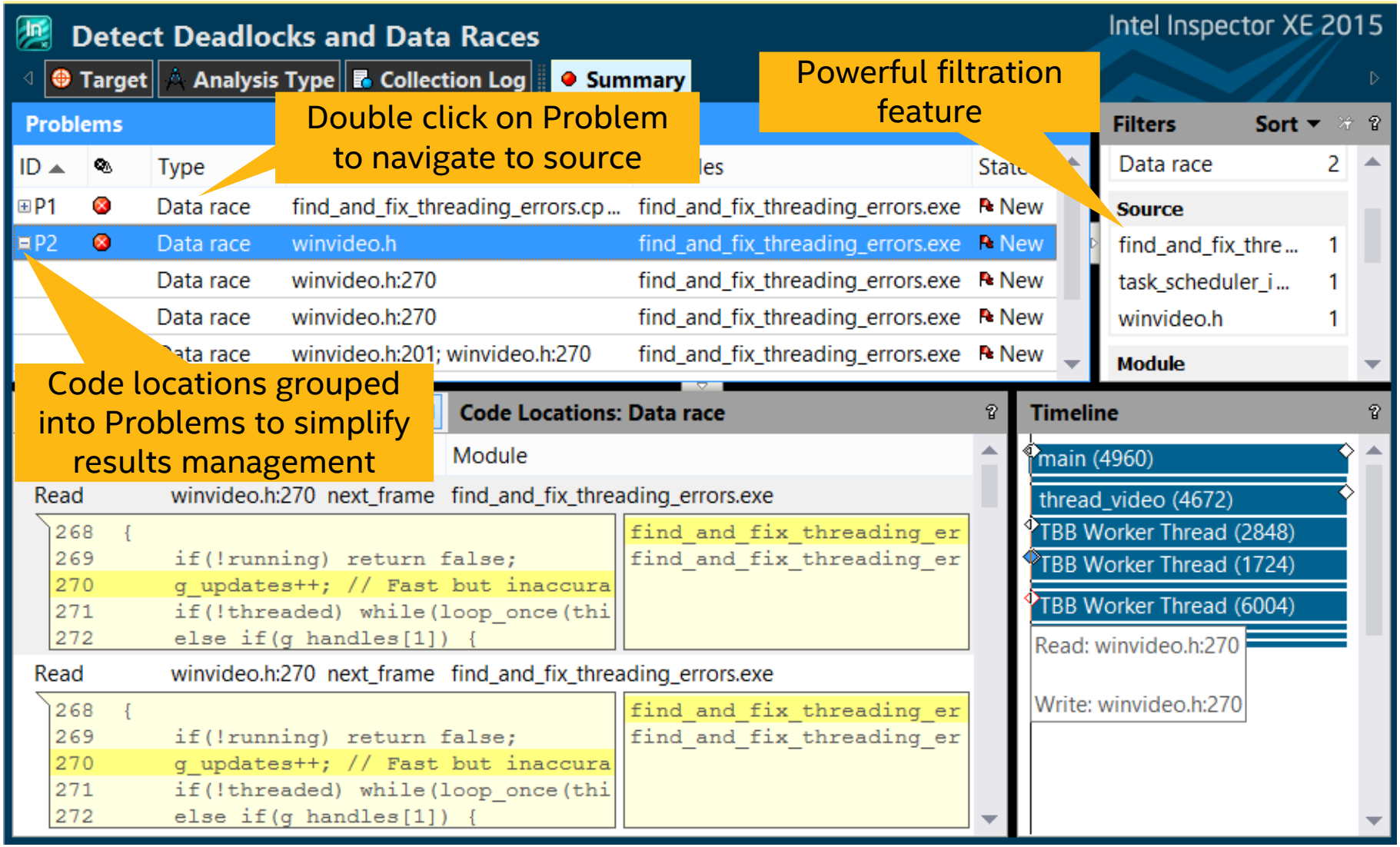
# Workflow: select analysis and start



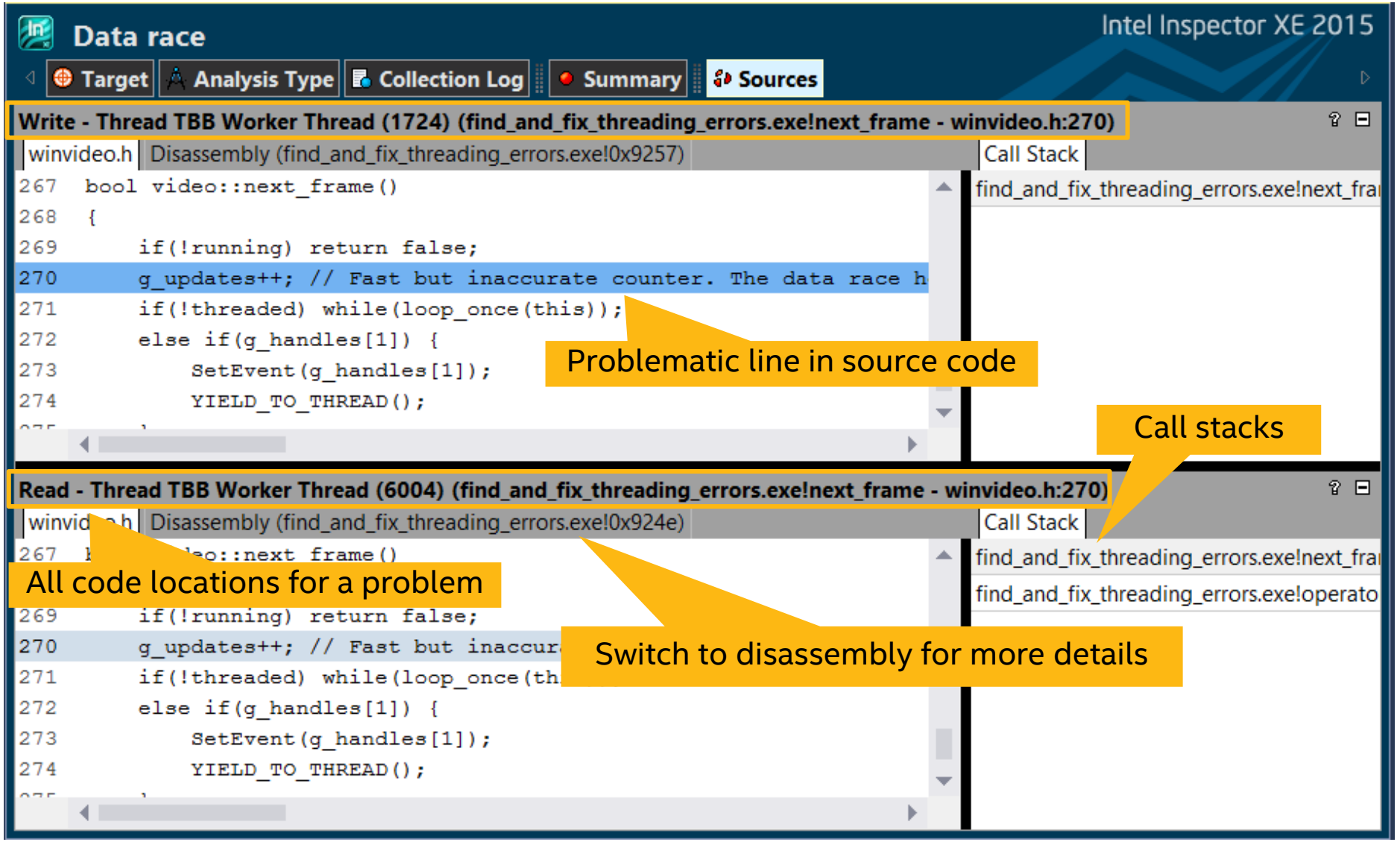
# Workflow: Dynamic Analysis



# Workflow: manage results



# Workflow: navigate to sources



# Memory problem analysis

# Memory problem Analysis

## Analyzed as software runs

- Data (workload) -driven execution
- Program can be single or multi-threaded
- Diagnostics reported incrementally as they occur

## Includes monitoring of:

- Memory allocation and allocating functions
- Memory deallocation and deallocating functions
- Memory leak reporting
- Inconsistent memory API usage

## Analysis scope

- Native code only: C, C++, Fortran
- Code path must be executed to be analyzed
- Workload size affects ability to detect a problem

# Memory problems

## Memory leak

- a block of memory is allocated
- never deallocated
- not reachable (there is no pointer available to deallocate the block)
- Severity level = (**Error**)

```
// Memory leak

char *pStr = (char*) malloc(512);
return;
```

## Memory not deallocated

- a block of memory is allocated
- never deallocated
- still reachable at application exit (there is a pointer available to deallocate the block).
- Severity level = (**Warning**)

```
// Memory not deallocated

static char *pStr = malloc(512);
return;
```

## Memory growth

- a block of memory is allocated
- not deallocated, within a specific time segment during application execution.
- Severity level = (**Warning**)

```
// Memory growth

// Start measuring growth
static char *pStr = malloc(512);
// Stop measuring growth
```

# Memory problems

## Uninitialized memory access

- Read of an uninitialized memory location

```
// Uninitialized Memory Access

void func()
{
   int a;
   int b = a * 4;
}
```

## Invalid Memory Access

- Read or write instruction references memory that is logically or physically invalid

```
// Invalid Memory Access

char *pStr = (char*) malloc(20);
free(pStr);
strcpy(pStr, "my string");
```

## Kernel Resource Leak

- Kernel object handle is created but never closed

```
// Kernel Resource Leak

HANDLE hThread = CreateThread(0,
     8192, work0, NULL, 0, NULL);
return;
```

## GDI Resource Leak

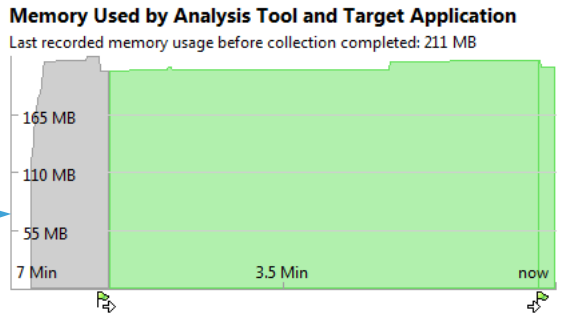
- GDI object is created but never deleted

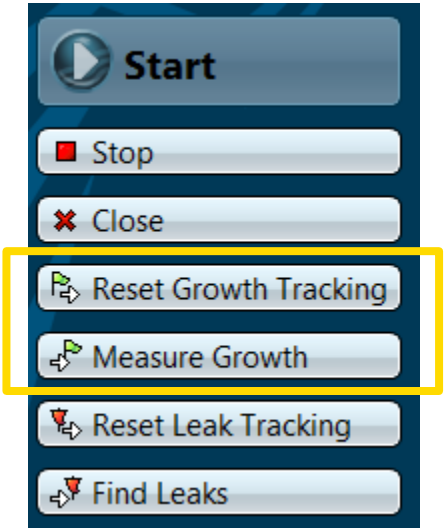
```
// GDI Resource Leak

HPEN pen = CreatePen(0, 0, 0);
return;
```

# Incrementally Diagnose Memory Growth

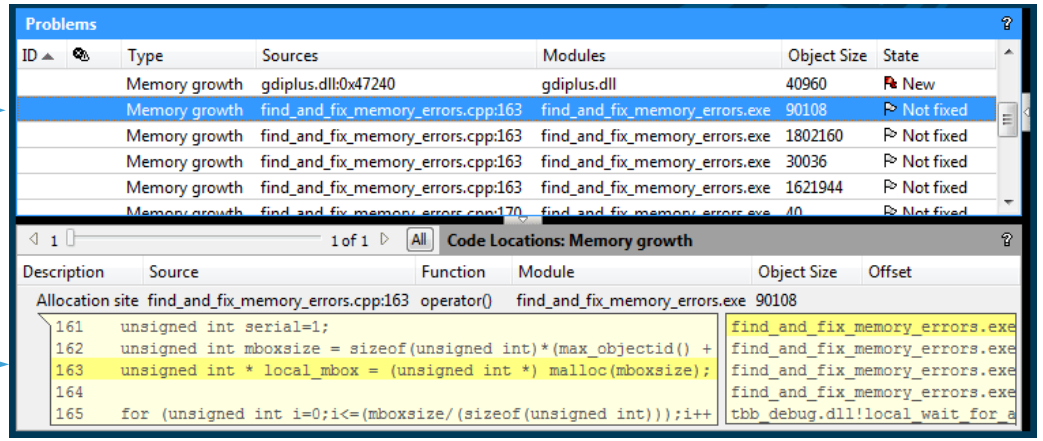
As your app is running…

Memory usage graph plots memory growth




Select a cause of memory growth




See the code snippet & call stack

# Threading problem analysis

# Threading problem Analysis

## Analyzed as software runs

- Data (workload) -driven execution
- Program needs to be multi-threaded
- Diagnostics reported incrementally as they occur

## Includes monitoring of:

- Thread and Sync APIs used
- Thread execution order
  - Scheduler impacts results
- Memory accesses between threads

## Analysis scope

- Native code: C, C++, Fortran
- Managed or mixed code: C# (.NET 2.0 to 3.5, .NET 4.0 with limitations)
- Code path must be executed to be analyzed
- Workload size doesn't affect ability to detect a problem

# Data race

```
CRITICAL_SECTION cs;           // Preparation
int *p = malloc(sizeof(int)); // Allocation Site
*p = 0;
InitializeCriticalSection(&cs);
```

## Write -> Write Data Race

Thread #1

```
*p = 1; // First Write
```

Thread #2

```
EnterCriticalSection(&cs);
*p = 2; // Second Write
LeaveCriticalSection(&cs);
```

## Read -> Write Data Race

Thread #1

```
int x;
x = *p; // Read
```

Thread #2

```
EnterCriticalSection(&cs);
*p = 2; // Write
LeaveCriticalSection(&cs);
```

# Deadlock

```
CRITICAL_SECTION cs1;
CRITICAL_SECTION cs2;
int x = 0;
int y = 0;
InitializeCriticalSection(&cs1); // Allocation Site (cs1)
InitializeCriticalSection(&cs2); // Allocation Site (cs2)
```

Thread #1

```
EnterCriticalSection(&cs1);
x++;
     EnterCriticalSection(&cs2);
     y++;
     LeaveCriticalSection(&cs2);
LeaveCriticalSection(&cs1);
```

Thread #2

```
EnterCriticalSection(&cs2);
y++;
     EnterCriticalSection(&cs1);
     x++;
     LeaveCriticalSection(&cs1);
LeaveCriticalSection(&cs2);
```

## Deadlock

1. EnterCriticalSection(&cs1); in thread #1
2. EnterCriticalSection(&cs2); in thread #2

## Lock Hierarchy Violation

1. EnterCriticalSection(&cs1); in thread #1
2. EnterCriticalSection(&cs2); in thread #1
3. EnterCriticalSection(&cs2); in thread #2
4. EnterCriticalSection(&cs1); in thread #2

# Cross-thread Stack Access

```
// A pointer visible for two threads
int *p;
CreateThread(..., thread #1, ...);
CreateThread(..., thread #2, ...);
```

Thread #1

```
// Allocated on Thread #1's stack
int q[1024];
p = q;
q[0] = 1;
```

Thread #2

```
// Thread #1's stack accessed
*p = 2;
```

# Integration with debugger

# Debugger integration

## Break into debugger

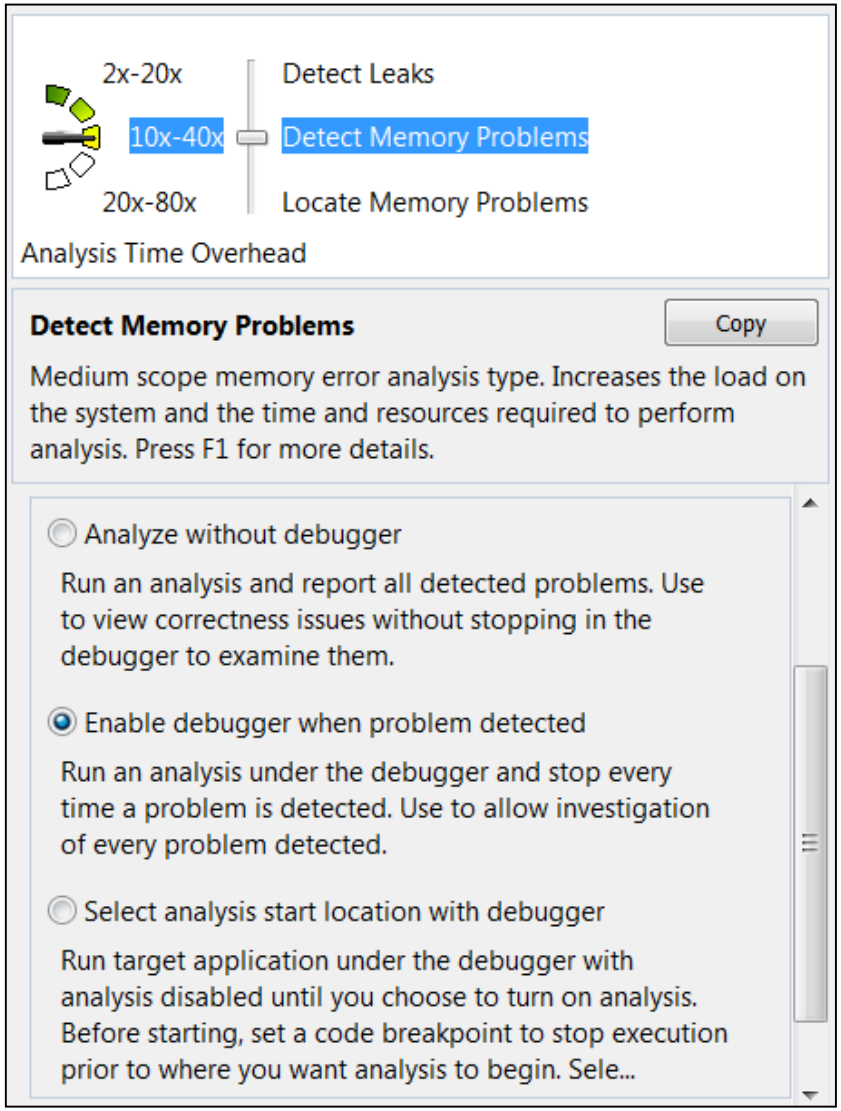
- Analysis can stop when it detects a problem
- User is put into a standard debugging session

## Windows*

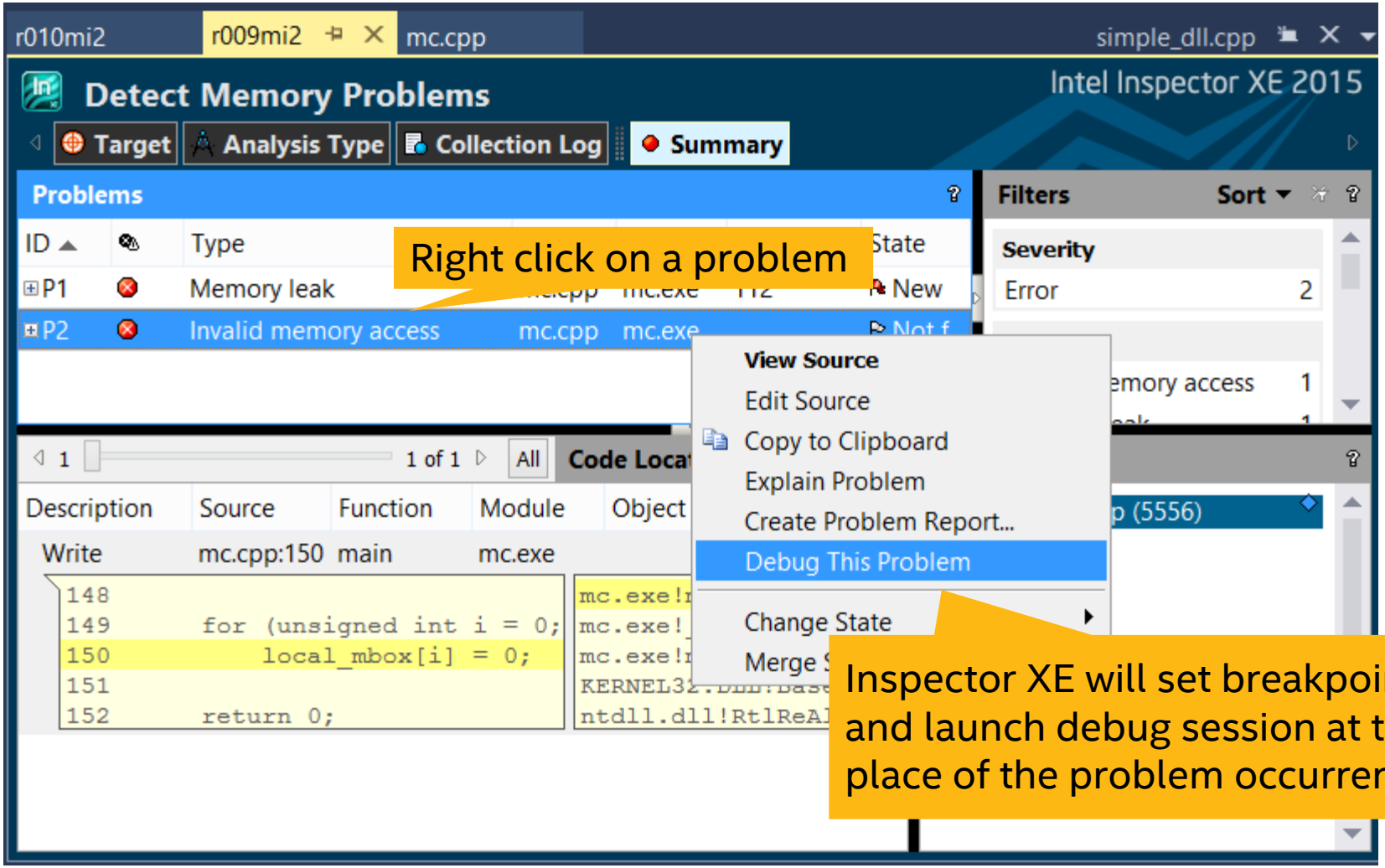
- Microsoft* Visual Studio Debugger (vs2012 – vs2015)

## Linux*

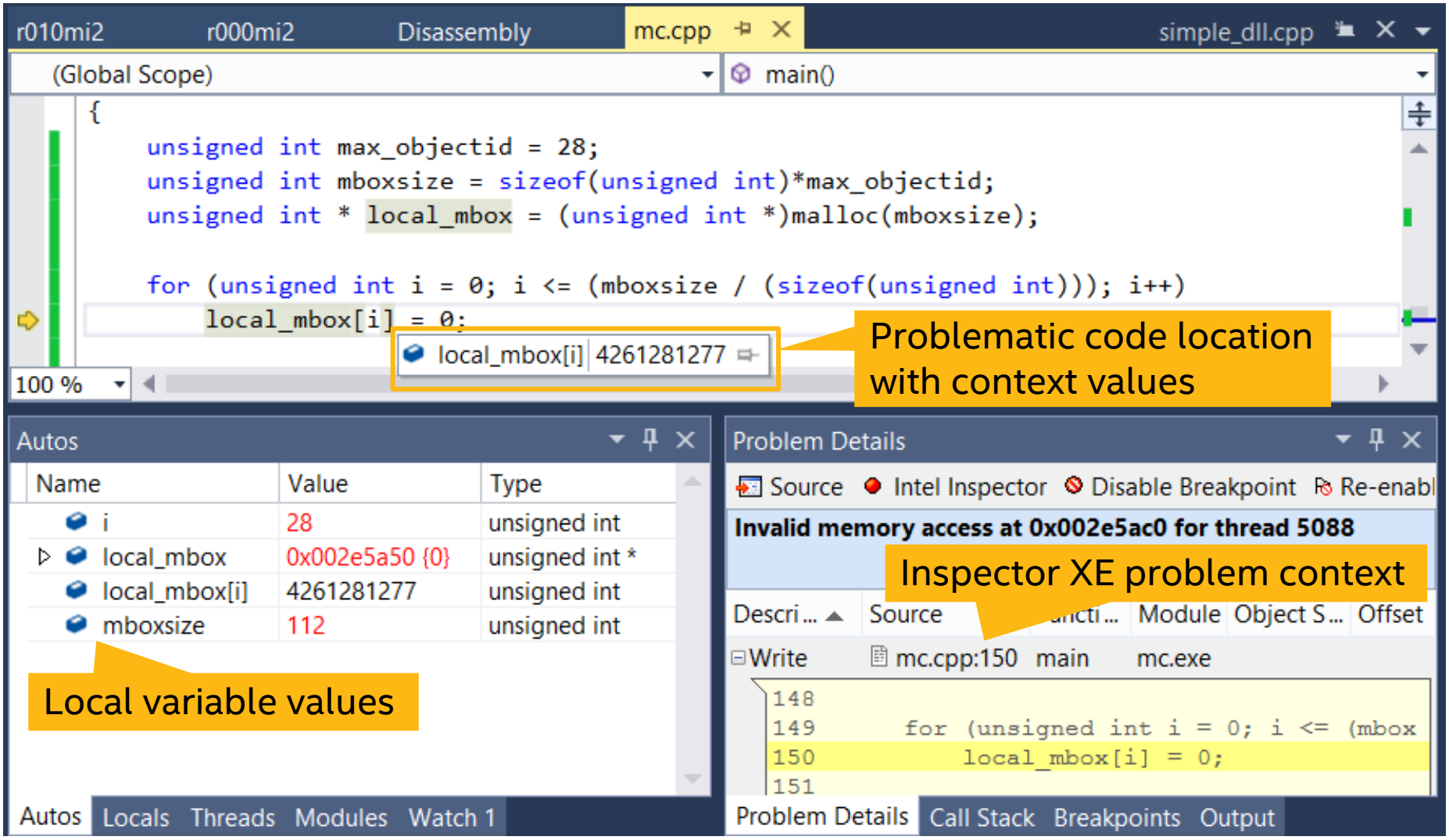
- gdb



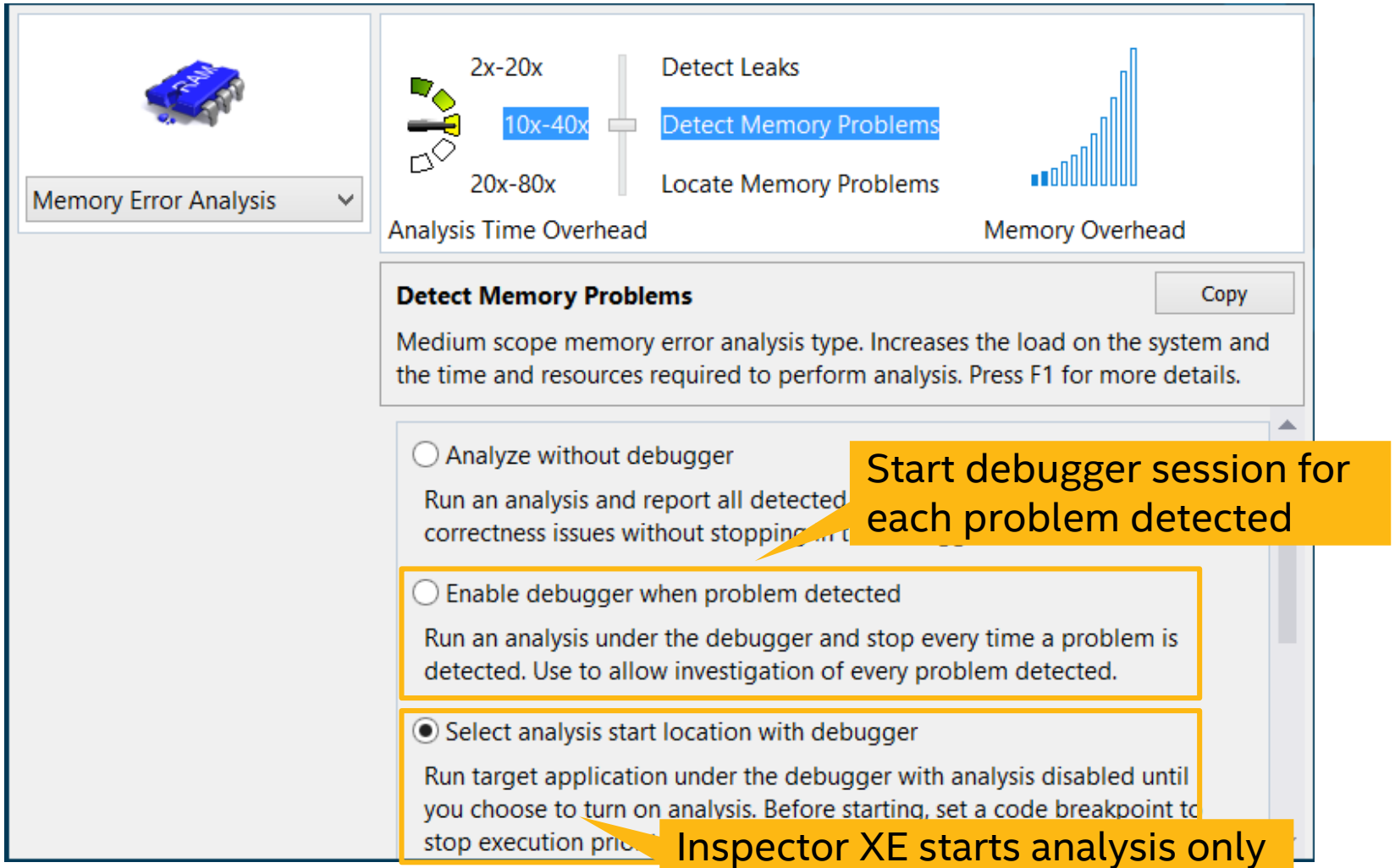
# Debug this problem



# Debug this problem



# Debugger options



# Regression testing and user API

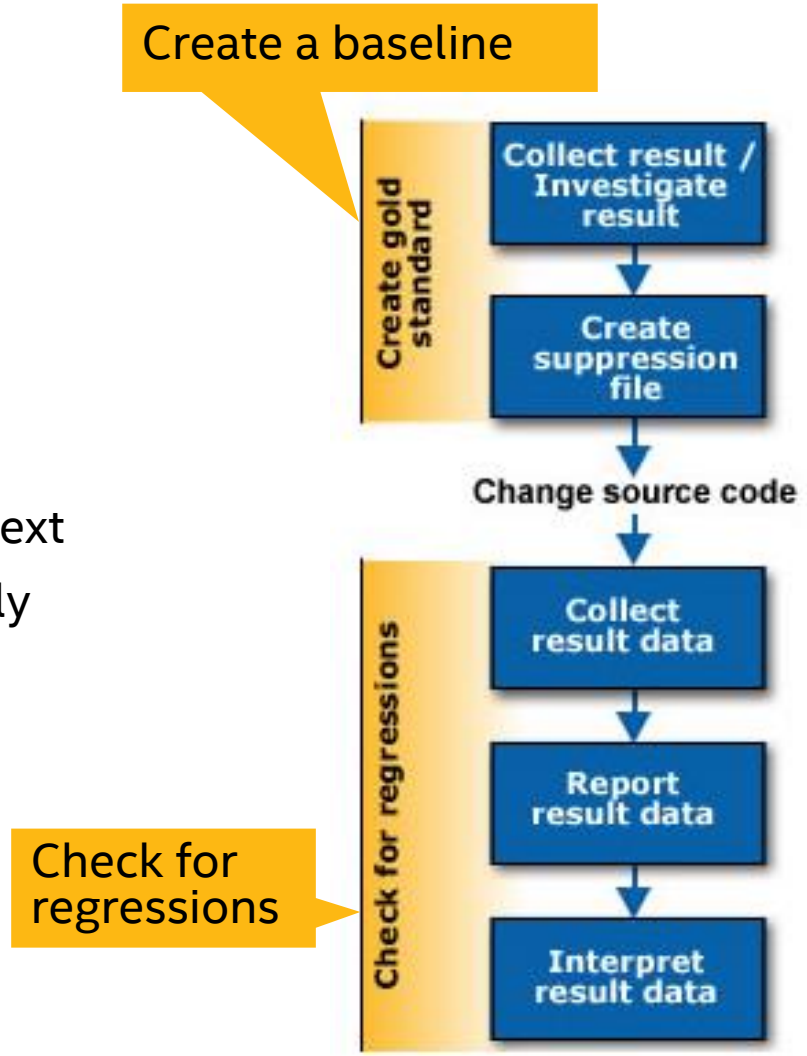
# Automate Regression Analysis

## Data collection from script

- Command line interface (CLI) for running analysis
- Child process analysis

## Reporting CLI

- Exporting results (pack and send)
- Text reports: XML, CSV and plain text
- Detect new problems automatically



# Automate Regression Analysis

## Command Line Interface

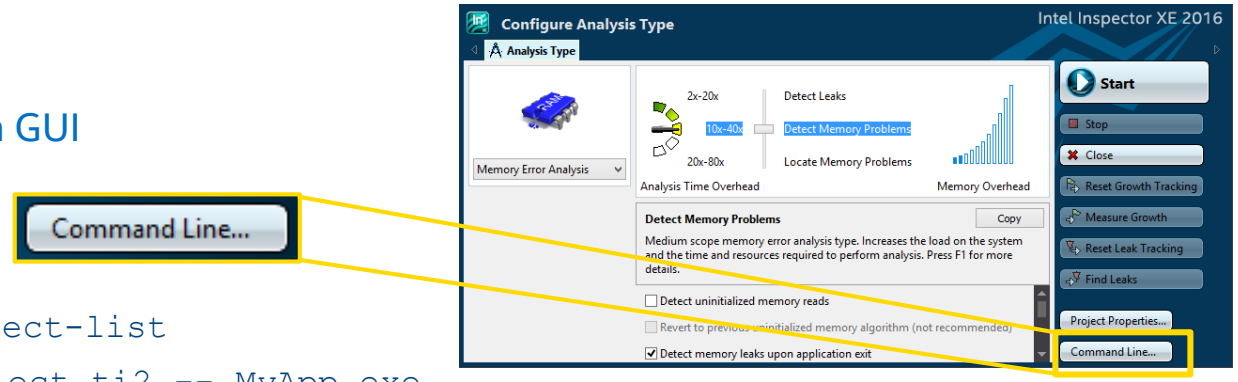
inspxe-cl is the command line:

- **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`

# Reporting: regression status

```
inspxe-cl -report status –r r002mi1

9 problem(s) found
    2 Investigated
    7 Not investigated
Breakdown by state:
    2 Confirmed
    4 Not fixed
    2 Regression
    1 New
```

# Intel Inspector XE: User APIs

## Enable you to

- Control collection, limit analysis scope
- Specify non-standard synchronization primitives
- Specify custom memory allocation primitives

## To use user APIs:

- Include `ittnotify.h`, located at `<install_dir>/include`
- Insert `__itt_*` notifications in your code
- Link to the `libittnotify.lib` file located at `<install_dir>/<lib32|lib64>`
- Available for C/C++ and Fortran

# Custom memory allocation

```
#include <ittnotify.h>

__itt_heap_function my_allocator;
__itt_heap_function my_reallocator;
__itt_heap_function my_freer;

void* my_malloc(size_t s)
{
    void* p;

    __itt_heap_allocate_begin (my_allocator, s, 0);
    p = user_defined_malloc (s);
    __itt_heap_allocate_end (my_allocator, &p, s, 0);

    return p;
}
... // Do similar markup for custom “realloc” and “free” operations

// Call this init routine before any calls to user defined allocators
void init_itt_calls()
{
    my_allocator = __itt_heap_function_create("my_malloc", "mydomain");
    my_reallocator = __itt_heap_function_create("my_realloc", "mydomain");
    my_freer = __itt_heap_function_create("my_free", "mydomain");
}
```

# Collection control APIs

| API | Description |
|---|---|
| `void __itt_suppress_push( unsigned int etype)` | Stop analyzing for errors on the current thread |
| `void __itt_suppress_pop ( void)` | Resume analysis |
| `void __itt_suppress_mark_range ( __itt_suppress_mode_t mode, unsigned int etype, void * address, size_t size);` | Suppress or unsuppress error detection for the specific memory range (object). |
| `void __itt_suppress_clear_range ( __itt_suppress_mode_t mode, unsigned int etype, void * address, size_t size);` | Clear the marked memory range |

# User-Defined Synchronization APIs

| API | Description |
|---|---|
| `void __itt_sync_acquired ( void *addr)` | Notify Intel Inspector that synchronization object is acquired by current thread |
| `void __itt_sync_releasing ( void *addr)` | Notify that the code is about to release the specified synchronization object |
| `void __itt_sync_destroy ( void *addr)` | Tell the Intel Inspector that the synchronization object will not be used again, so the Intel Inspector can dispose of bookkeeping information associated with this object. |

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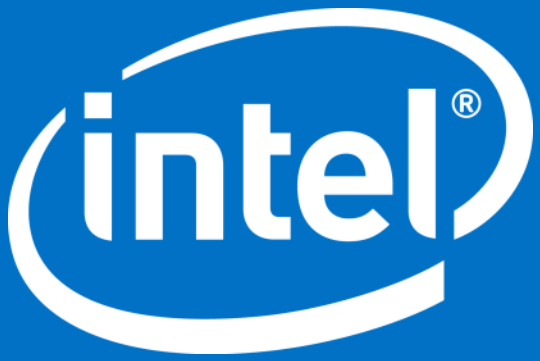
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