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Memory Safety: Static vs Dynamic Analysis

Open4Tech

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@ciura_victor

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CAPHYON

Abstract

Clang-tidy is the go-to assistant for most C/C++ programmers looking to improve their code, whether to modernize it or to find hidden bugs with its built-in checks. Static analysis is great, but you also get tons of false positives.

Dynamic/runtime analysis, on the other hand, can catch more classes of memory vulnerabilities, but comes with its own costs.

Let's see how AddressSanitizer works behind the scenes (compiler and ASAN runtime) and analyze the instrumentation impact, both in perf and memory footprint. We'll examine a handful of examples diagnosed by ASAN and see how easy it is to read memory snapshots to pinpoint the failure.

Ask questions as we go...

Q & A

Humans Depend on Tools

Get to know your tools

well

Programmers Depend on Tools

good code editor
(or IDE)

linter/formatter

powerful (visual) debugger

automated refactoring tools

build system

package manager

SCM client

CI/CD service

code reviews platform

recent compiler(s)
[conformant/strict]

perf profiler

test framework

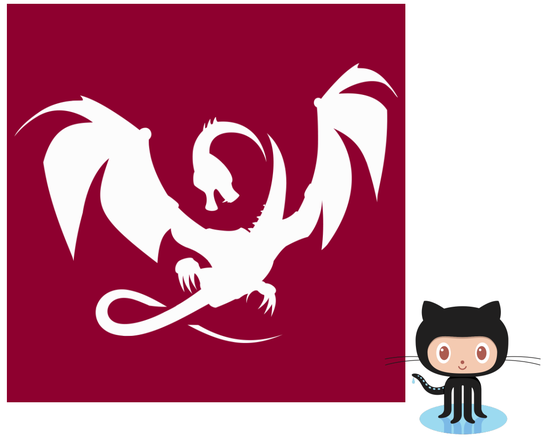
static analyzer

dynamic analyzer
(runtime)

+ fuzzing

I'm a tool maker

Advanced Installer



Clang Power Tools

Free/OSS

@ciura_victor

Part I

Static Analysis

C++ Core Guidelines Checker

docs.microsoft.com/en-us/cpp/code-quality/quick-start-code-analysis-for-c-cpp

docs.microsoft.com/en-us/cpp/code-quality/code-analysis-for-cpp-corecheck

devblogs.microsoft.com/cppblog/new-safety-rules-in-c-core-check/

Static Analysis

Visual Studio integrates with:

- MSVC Code Analysis: https://aka.ms/cpp/ca/bg
- Clang Tidy: https://aka.ms/cpp/clangtidy
- VS Code Linters: https://aka.ms/cpp/linter

Closing the Gap between Rust and C++ Using Principles of Static Analysis
youtube.com/watch?v=_pQGRr4P16w

clang-tidy

300+ checks

clang.llvm.org/extra/clang-tidy/checks/list.html

clang-tidy

- modernize-use-nullptr
- modernize-loop-convert
- modernize-use-override
- readability-redundant-string-cstr
- modernize-use-emplace
- modernize-use-auto
- modernize-make-shared & modernize-make-unique
- modernize-use-equals-default & modernize-use-equals-delete

clang-tidy

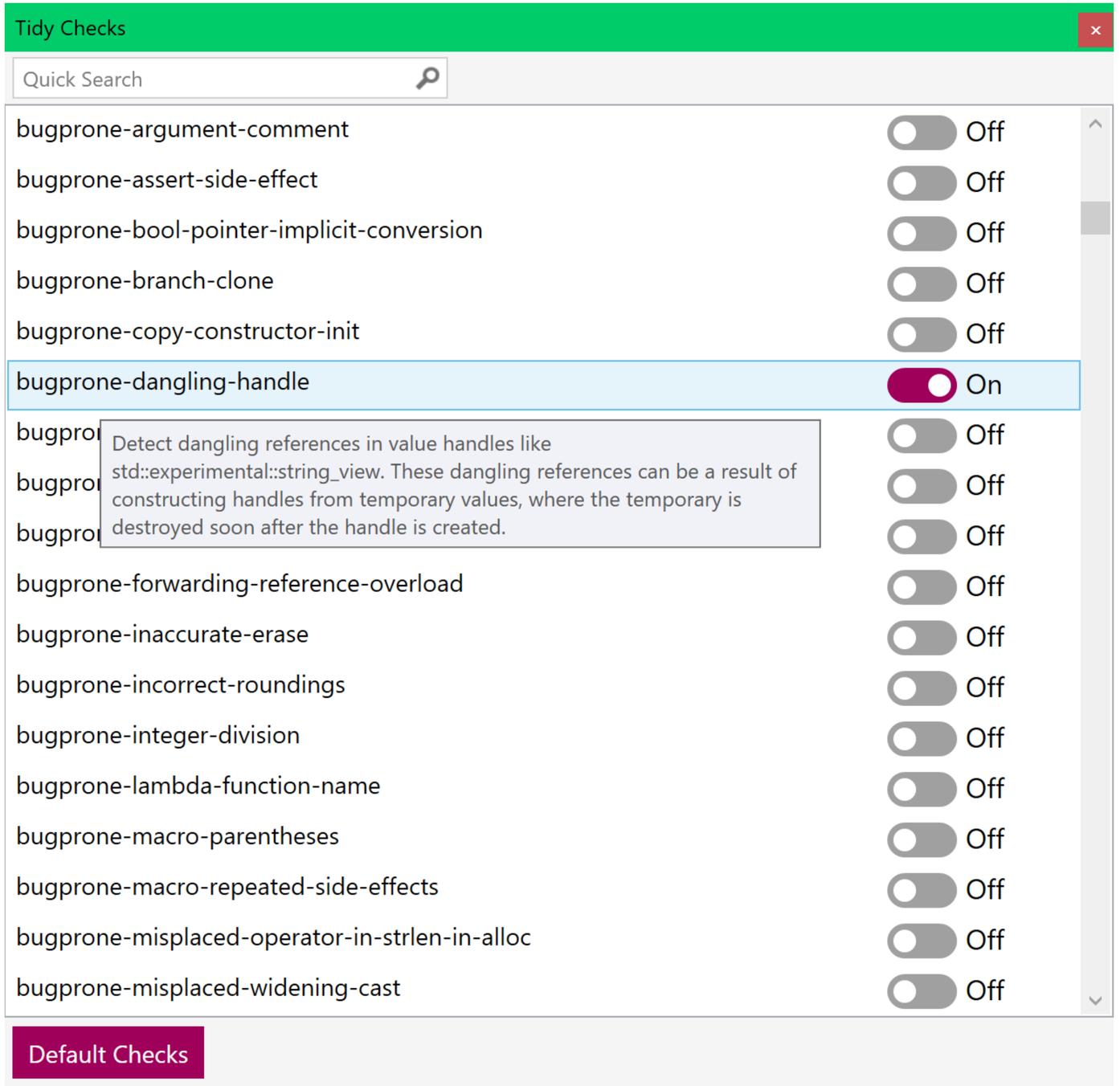
- modernize-use-default-member-init
- readability-redundant-member-init
- modernize-pass-by-value
- modernize-return-braced-init-list
- modernize-use-using
- cppcoreguidelines-pro-type-member-init
- readability-redundant-string-init & misc-string-constructor
- misc-suspicious-string-compare & misc-string-compare
- misc-inefficient-algorithm
- cppcoreguidelines-*

clang-tidy

- abseil-string-find-startswith
- boost-use-to-string
- bugprone-string-constructor
- bugprone-string-integer-assignment
- bugprone-string-literal-with-embedded-nul
- bugprone-suspicious-string-compare
- modernize-raw-string-literal
- performance-faster-string-find
- performance-inefficient-string-concatenation
- readability-redundant-string-cstr
- readability-redundant-string-init
- readability-string-compare

`string` checks

`clang-tidy` checks



`clang-tidy` `bugprone-dangling-handle`

> Detect dangling references in value handles like `std::string_view`

These dangling references can be a result of constructing handles from ***temporary*** values, where the temporary is destroyed **soon** after the handle is created.

Options:

👉 `HandleClasses`
A semicolon-separated list of class names that should be treated as handles. By default only `std::string_view` is considered.

https://clang.llvm.org/extra/clang-tidy/checks/bugprone-dangling-handle.html

Lifetime safety: Preventing common dangling

This is important because it turns out to be ***easy*** to convert **[by design]**

a `std::string` to a `std::string_view`,

or a `std::vector/array` to a `std::span`,

so that dangling is almost the default behavior.

`CppCoreGuidelines`

https://github.com/isocpp/CppCoreGuidelines/blob/master/docs/Lifetime.pdf

Lifetime safety: Preventing common dangling

`[-Wdangling-gsl]` **diagnosed by default since Clang 10**

warning: initializing pointer member to point to a temporary object whose lifetime is shorter than the lifetime of the constructed object

```
void example()
{
  std::string_view sv = std::string("dangling");


  std::cout << sv;
}
```

https://clang.llvm.org/docs/DiagnosticsReference.html#wdangling-gsl

Lifetime safety: Preventing common dangling

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warning: initializing pointer member to point to a temporary object whose lifetime is shorter than the lifetime of the constructed object

```
void example()
{
  std::string_view sv = std::string("dangling");
                  // warning: object backing the pointer will be destroyed
                  // at the end of the full-expression [-Wdangling-gsl]
  std::cout << sv;
}
```

https://clang.llvm.org/docs/DiagnosticsReference.html#wdangling-gsl

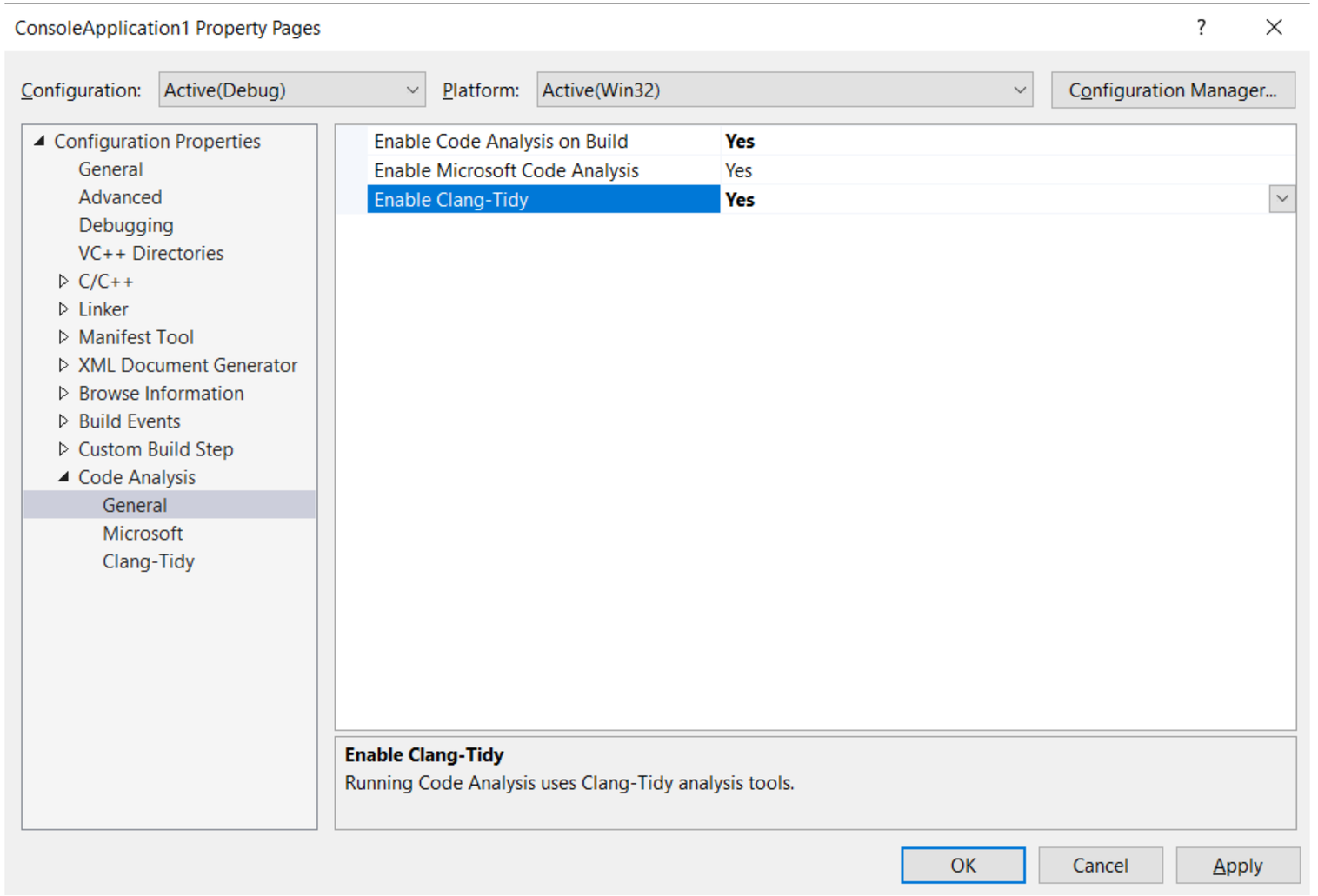
Visual Studio 2019
since v16.4

`clang-tidy`

code analysis

https://devblogs.microsoft.com/cppblog/code-analysis-with-clang-tidy-in-visual-studio/

Visual Studio 2019/2022



Visual Studio 2019/2022

`clang-tidy` warnings

Error List

Entire Solution | 0 Errors | 10 Warnings | 0 Messages | Build + IntelliSense

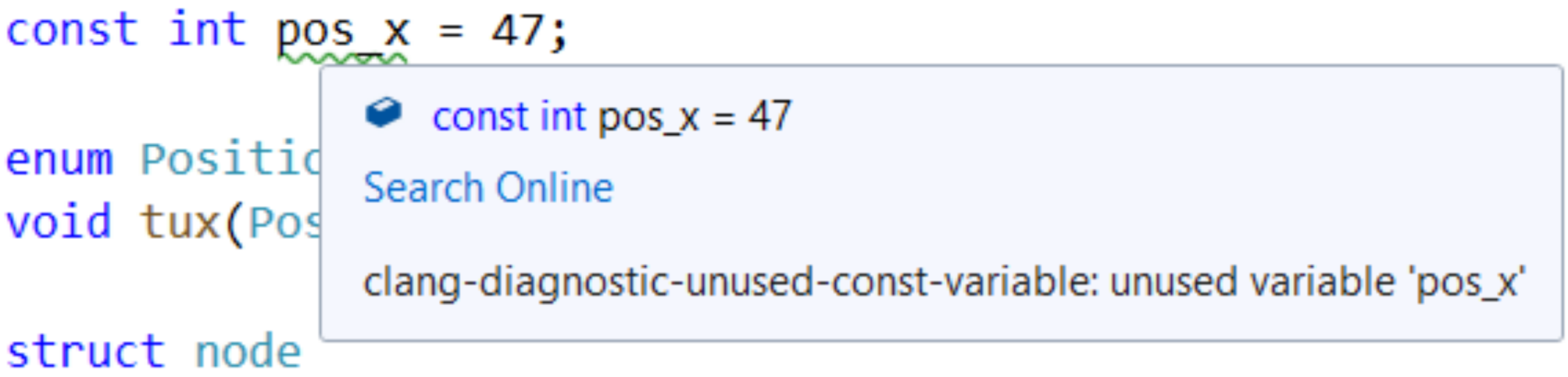
Code	Description	File	Line	Col	Category
readability-isolate-declaration	multiple declarations in a single statement reduces readability	CMAKEDEMO.CPP	23	2	readability
modernize-use-nullptr	use nullptr	CMAKEDEMO.CPP	31	7	modernize
cppcoreguidelines-macro-usage	macro 'TRUE' used to declare a constant; consider using a 'constexpr' constant	CMAKEDEMO.CPP	35	9	cppcoreguidelines
clang-diagnostic-unused-variable	unused variable 'local'	CMAKEDEMO.CPP	50	13	clang-diagnostic
clang-diagnostic-unused-const-variable	unused variable 'pos_x'	CMAKEDEMO.CPP	36	11	clang-diagnostic
clang-diagnostic-uninitialized	variable 'numLives' is uninitialized when used here	CMAKEDEMO.CPP	24	3	clang-diagnostic
clang-diagnostic-return-type	control reaches end of non-void function	CMAKEDEMO.CPP	32	1	clang-diagnostic
clang-analyzer-core.NullDereference	Dereference of undefined pointer value	CMAKEDEMO.CPP	24	12	clang-analyzer

Error List | Output

https://devblogs.microsoft.com/cppblog/code-analysis-with-clang-tidy-in-visual-studio/

Visual Studio 2019/2022

`clang-tidy` **warnings also display as in-editor squiggles**



Code Analysis runs automatically in the background

=

->

Free/OSS

Clang Power Tools

www.clangpowertools.com

LLVM

clang-tidy

clang++

clang-format

clang-check/query

Visual Studio

2017 / 2019 / 2022

Static vs Dynamic Analysis

Static Analysis

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- vicious cycle: type propagation <> alias analysis

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0 false positives!

Part II

Dynamic Analysis

ICYMI

Control Flow Guard

`/guard:cf`

Enforce control flow integrity (Windows 8.1/10/11)

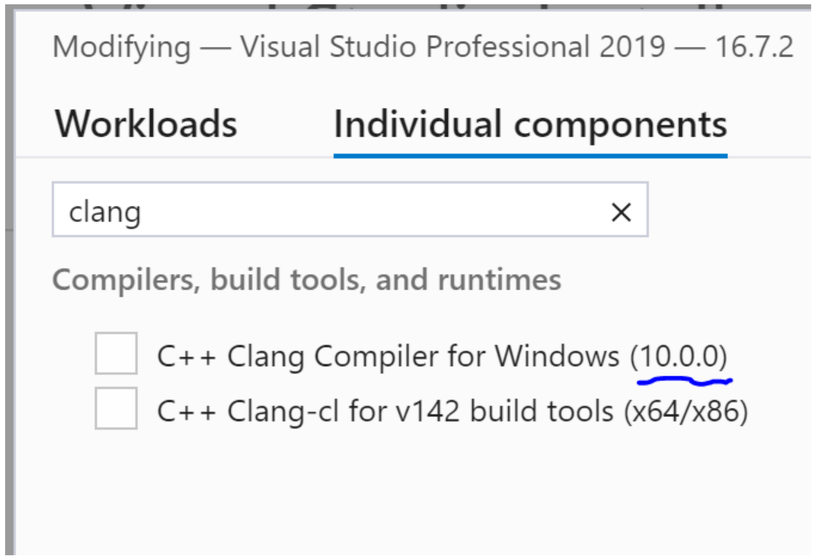
CFG is complementary to other exploit mitigations, such as:

- Address Space Layout Randomization (**ASLR**)
- Data Execution Prevention (**DEP**)

MSVC

CFG is now supported in **LLVM 10+**

C++ & Rust



https://aka.ms/cpp/cfg-llvm

Sanitizers

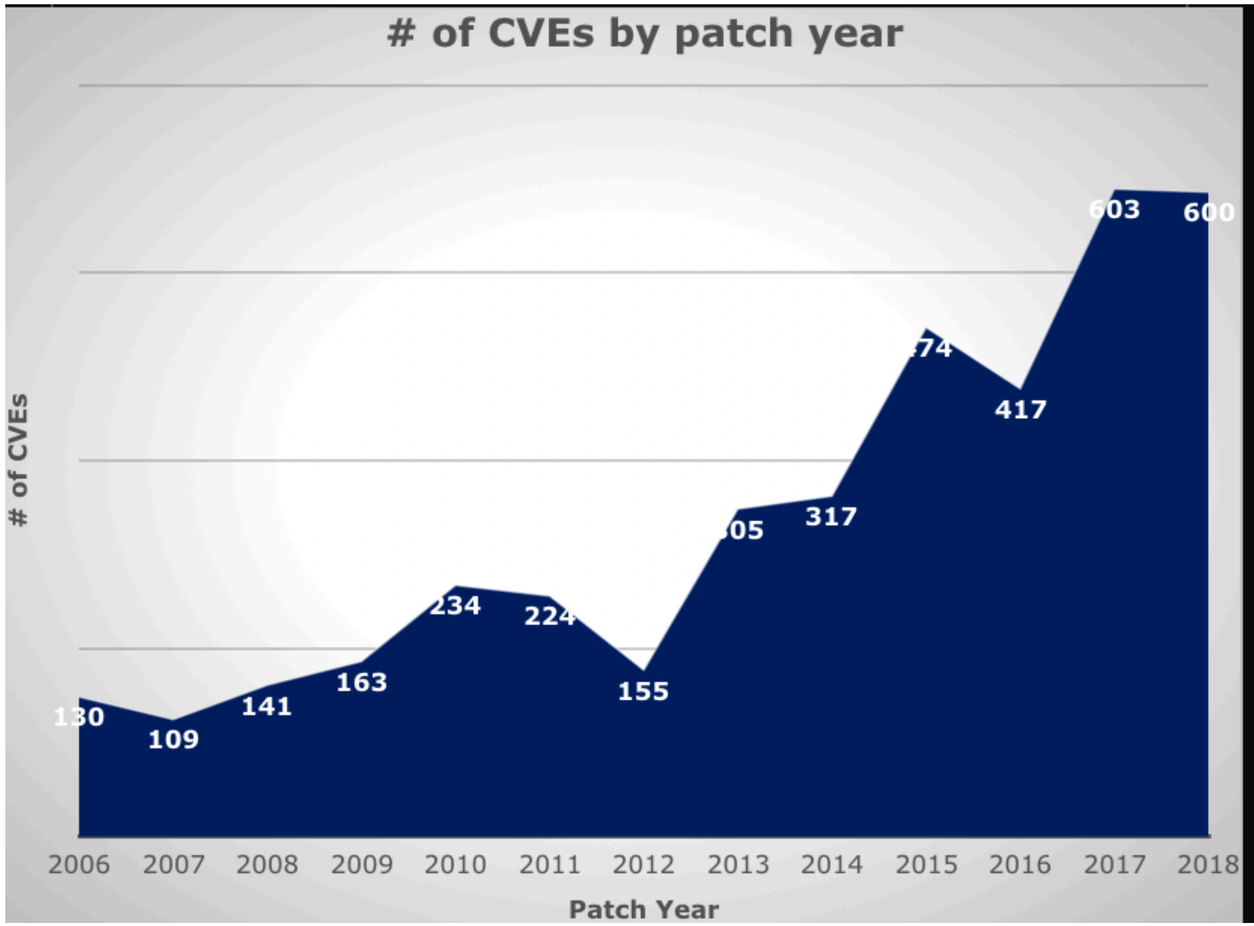
Sanitizers

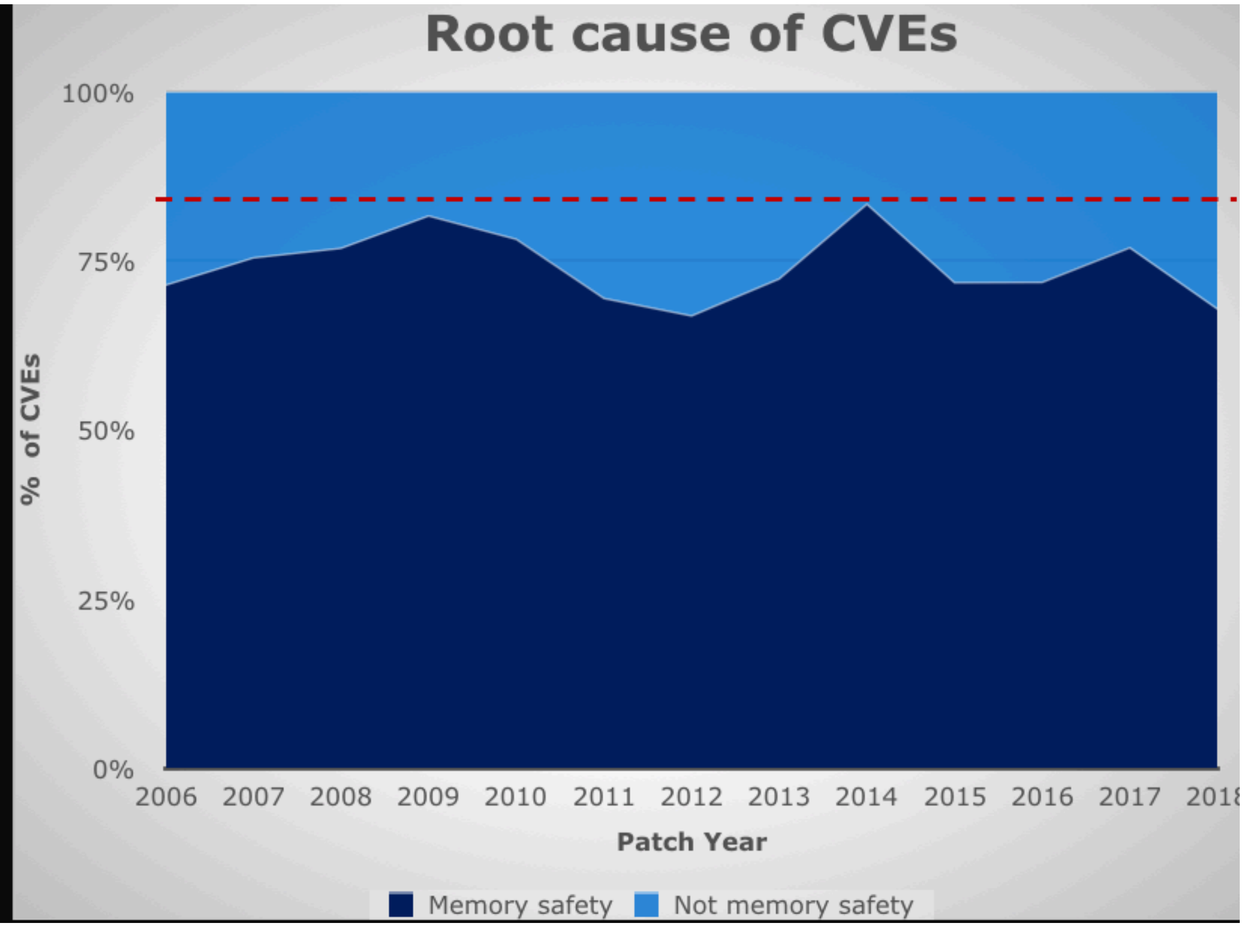
- `AddressSanitizer` - detects addressability issues
- `LeakSanitizer` - detects memory leaks
- `ThreadSanitizer` - detects data races and deadlocks
- `MemorySanitizer` - detects use of uninitialized memory
- `HWASAN` - hardware-assisted AddressSanitizer (consumes less memory)
- `UBSan` - detects Undefined Behavior

github.com/google/sanitizers

Common Vulnerabilities and Exposures

Memory safety continues to dominate





youtube.com/watch?v=0EsqxGgYOQU

Address Sanitizer (ASan)

De facto standard for detecting memory safety issues

It's important for basic correctness and sometimes true vulnerabilities

github.com/google/sanitizers/wiki/AddressSanitizer

Address Sanitizer (ASan)

Detects:

- **Use after free** (dangling pointer dereference)
- **Heap buffer overflow**
- **Stack buffer overflow**
- **Global buffer overflow**
- **Use after return**
- **Use after scope**
- **Initialization order bugs**
- **Memory leaks**

github.com/google/sanitizers/wiki/AddressSanitizer

Address Sanitizer (ASan)

Started in **LLVM** by a team @ Google

and quickly took off as a *de facto* industry standard

for runtime program analysis

github.com/google/sanitizers/wiki/AddressSanitizer

Address Sanitizer (ASan)

LLVM starting with version **3.1** (2012)

GCC starting with version **4.8** (2013)

MSVC starting with VS **16.4** (2019)

Visual Studio 2019
since v16.4

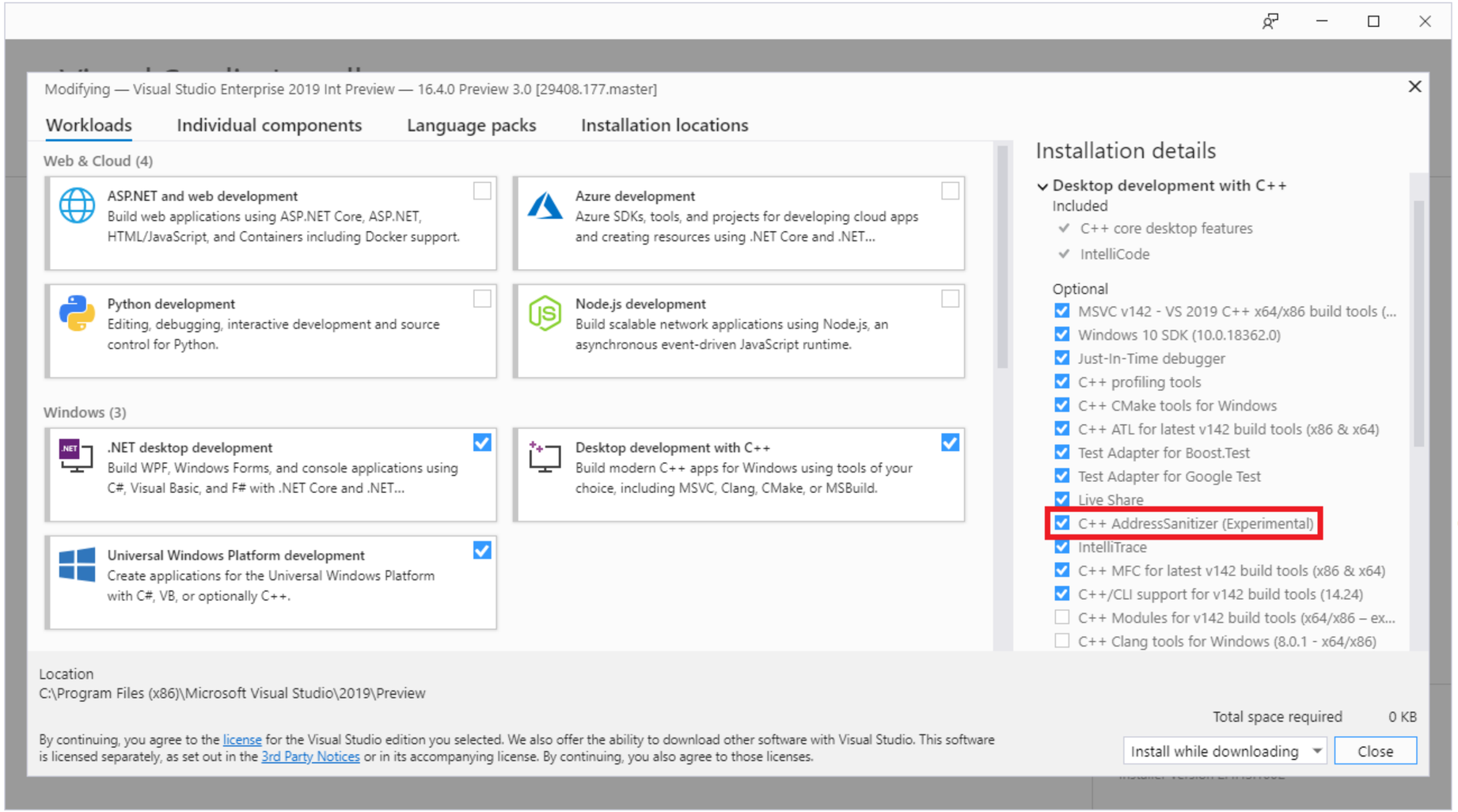
October 2019

Address Sanitizer
(ASan)

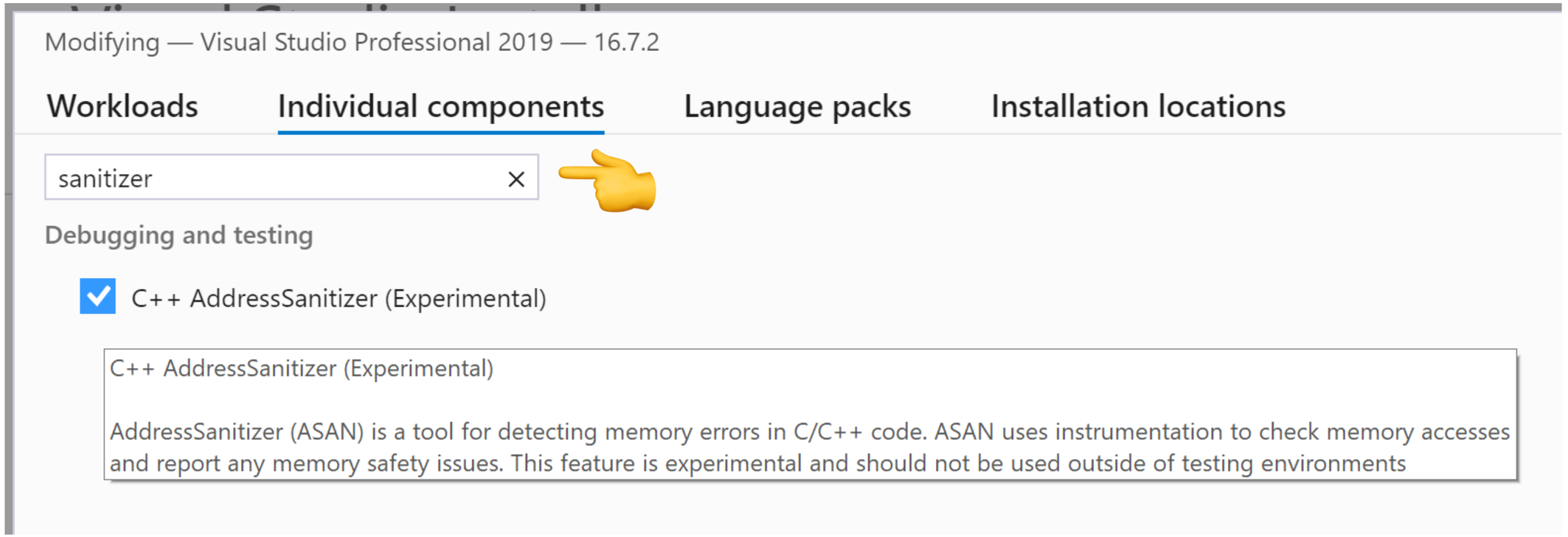
🎉

devblogs.microsoft.com/cppblog/addresssanitizer-asan-for-windows-with-msvc/

Visual Studio 2019/2022

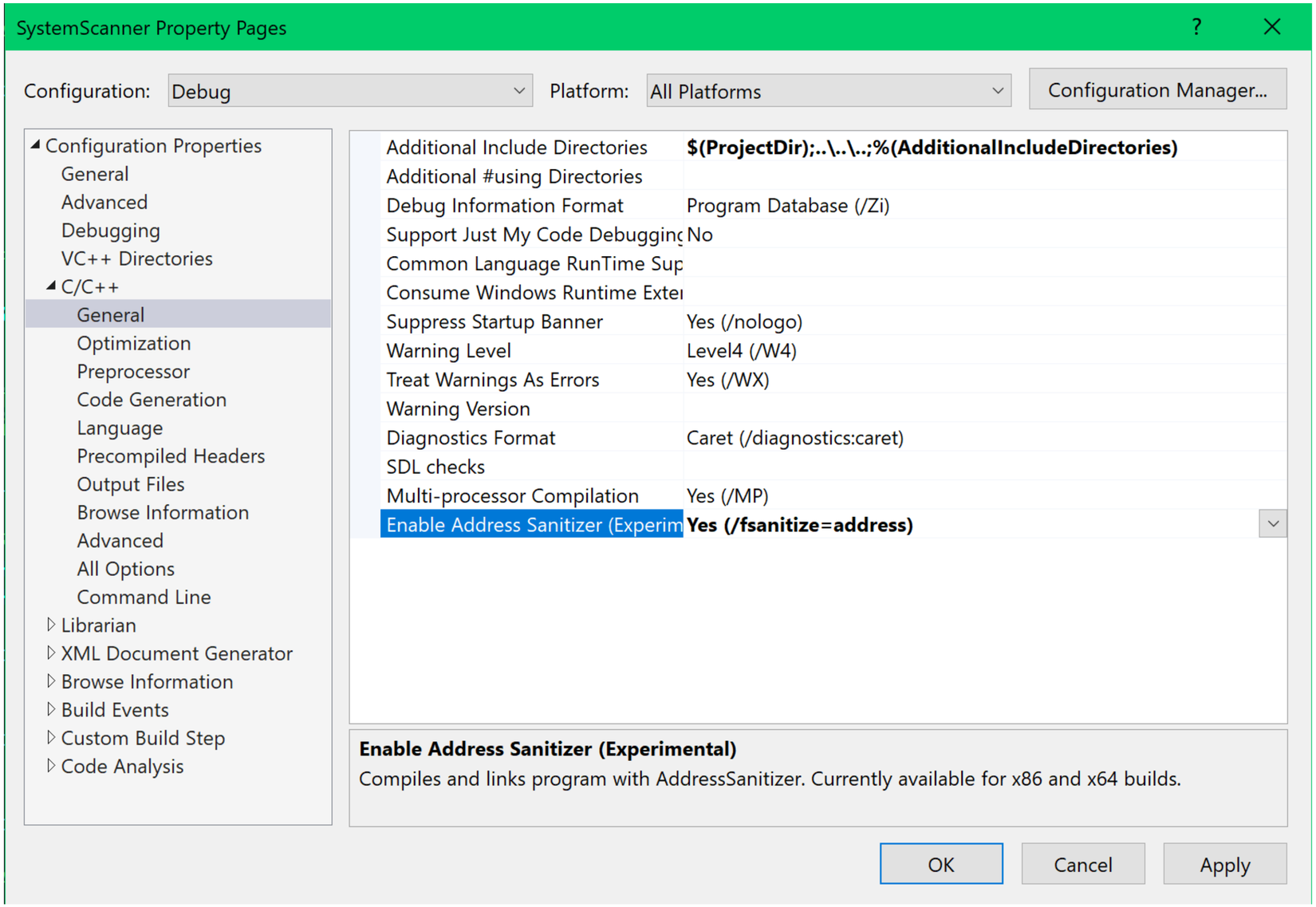


Visual Studio 2019/2022



ASAN is out of Experimental since v16.9

Visual Studio 2019/2022



ASan features:

- stack-use-after-scope
- stack-buffer-overflow
- stack-buffer-underflow
- heap-buffer-overflow (no underflow)
- heap-use-after-free
- calloc-overflow
- dynamic-stack-buffer-overflow (alloca)
- global-overflow (C++ source code)
- new-delete-type-mismatch
- memcpy-param-overlap
- allocation-size-too-big
- invalid-aligned-alloc-alignment
- use-after-poison
- intra-object-overflow
- initialization-order-fiasco
- double-free
- alloc-dealloc-mismatch

docs.microsoft.com/en-us/cpp/sanitizers/asan

ASan features:

- `global 'C' variables`
  (in C a global can be declared many times, and each declaration can be of a different type and size)

- `__declspec(no_sanitize_address)`
  (**opt-out** of instrumenting entire functions or specific variables)

- `automatically link appropriate ASan libs`
  (eg. when building from command-line with `/fsanitize:address`)

- `use-after-return (opt-in)`
  (requires code gen that utilizes two stack frames for each function)

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```
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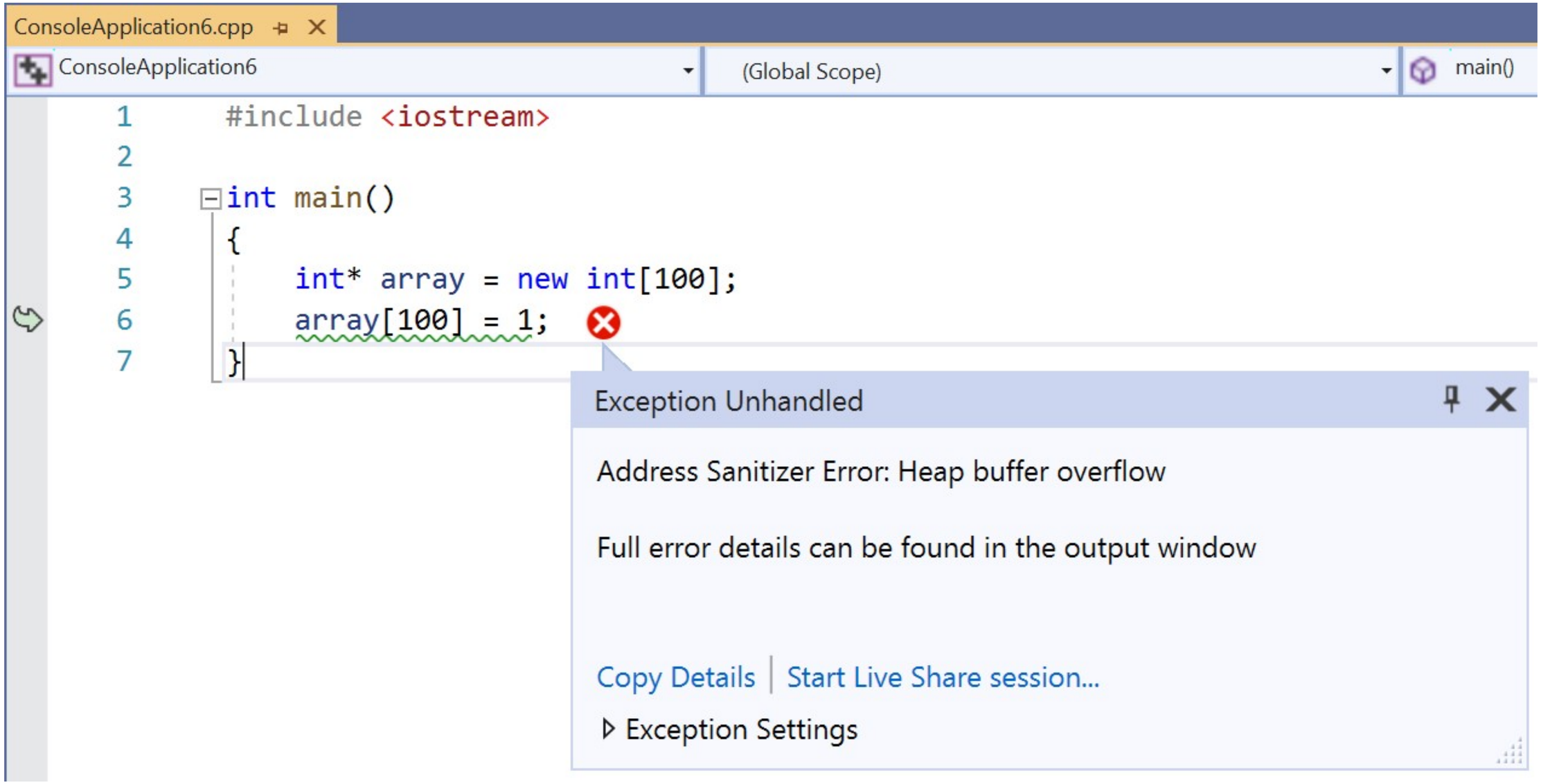
- compiler/linker will suggest emitting debug information when building with ASan

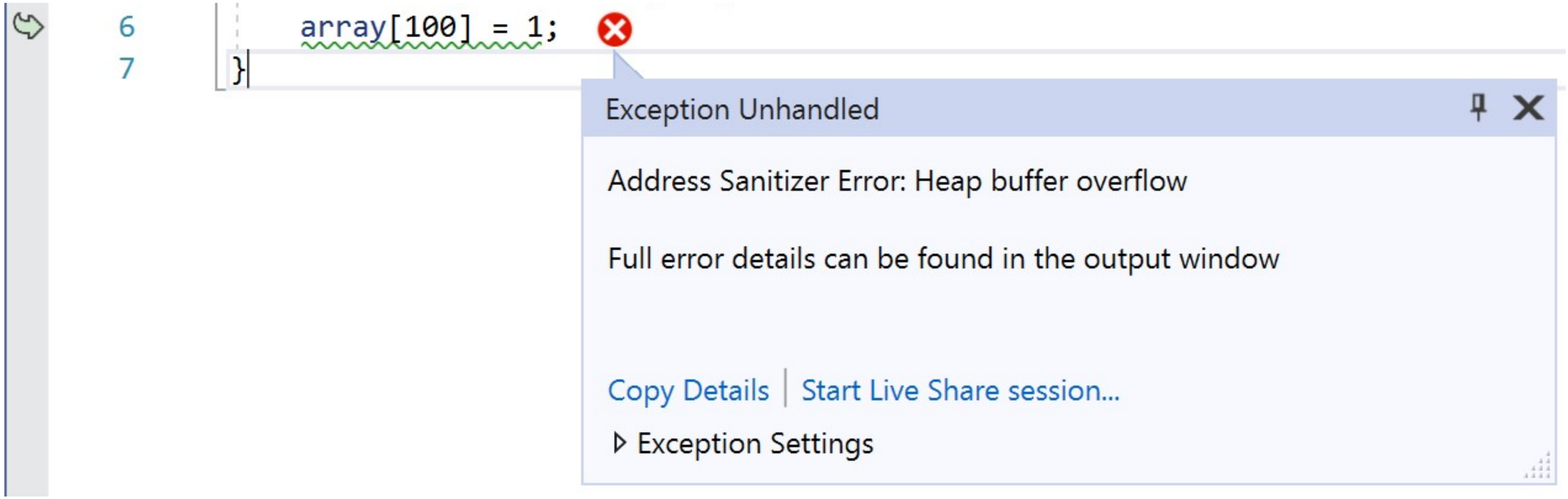
Address Sanitizer (ASan)



Address Sanitizer (ASan)

IDE Exception Helper will be displayed when an issue is encountered
=> program execution will stop

ASan logging information => Output window



Clang/LLVM

```
==27748==ERROR: AddressSanitizer: stack-use-after-scope on address 0x0055fc68 at pc 0x793d62de bp 0x0055fbf4 sp 0x0055fbe8
WRITE of size 80 at 0x0055fc68 thread T0
    #0 0x793d62f6 in __asan_wrap_memset d:\_work\5\s\llvm\projects\compiler-rt\lib\sanitizer_common\sanitizer_common_interceptors.inc:764
    #1 0x77dd46e7  (C:\WINDOWS\SYSTEM32\ntdll.dll+0x4b2c46e7)
    #2 0x77dd4ce1  (C:\WINDOWS\SYSTEM32\ntdll.dll+0x4b2c4ce1)
    #3 0x75d408fe  (C:\WINDOWS\System32\KERNELBASE.dll+0x100f08fe)
    #4 0xa5ada0 in try_get_first_available_module minkernel\crts\ucrt\src\appcrt\internal\winapi_thunks.cpp:271
    #5 0xa5ae99 in try_get_function minkernel\crts\ucrt\src\appcrt\internal\winapi_thunks.cpp:326
    #6 0xa5b028 in __acrt_AppPolicyGetProcessTerminationMethodInternal minkernel\crts\ucrt\src\appcrt\internal\winapi_thunks.cpp:737
    #7 0xa606ad in __acrt_get_process_end_policy minkernel\crts\ucrt\src\appcrt\internal\win_policies.cpp:84
    #8 0xa52dcb in exit_or_terminate_process minkernel\crts\ucrt\src\appcrt\startup\exit.cpp:134
    #9 0xa52da7 in common_exit minkernel\crts\ucrt\src\appcrt\startup\exit.cpp:280
    #10 0xa52fb6 in exit minkernel\crts\ucrt\src\appcrt\startup\exit.cpp:293
    #11 0xa2deb3 in _scrt_common_main_seh d:\agent\_work\2\s\src\vctools\crt\vcstartup\src\startup\exe_common.inl:295
    #12 0x75ef6358  (C:\WINDOWS\System32\KERNEL32.DLL+0x6b816358)
    #13 0x77df7a93  (C:\WINDOWS\SYSTEM32\ntdll.dll+0x4b2e7a93)

Address 0x0055fc68 is located in stack of thread T0
SUMMARY: AddressSanitizer: stack-use-after-scope d:\compiler-rt\lib\sanitizer_common\sanitizer_common_interceptors.inc:764 in __asan_wrap_memset
Shadow bytes around the buggy address:
  0x300abf30: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x300abf70: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=>0x300abf80: 00 00 00 00 00 00 00 00 00 00 00 00 00[f8]00 00
  0x300abf90: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x300abfd0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
Shadow byte legend (one shadow byte represents 8 application bytes):
  Addressable:           00
  Partially addressable: 01 02 03 04 05 06 07
  Heap left redzone:       fa
  Freed heap region:       fd
  Stack left redzone:      f1
  Stack mid redzone:       f2
  Stack right redzone:     f3
  Stack after return:      f5
  Stack use after scope:   f8
  Global redzone:          f9
  Global init order:       f6
  Poisoned by user:        f7
  Container overflow:      fc
  Array cookie:            ac
  Intra object redzone:    bb
  ASan internal:           fe
  Left alloca redzone:     ca
  Right alloca redzone:    cb
  Shadow gap:              cc
==27748==ABORTING
```

Snapshot File

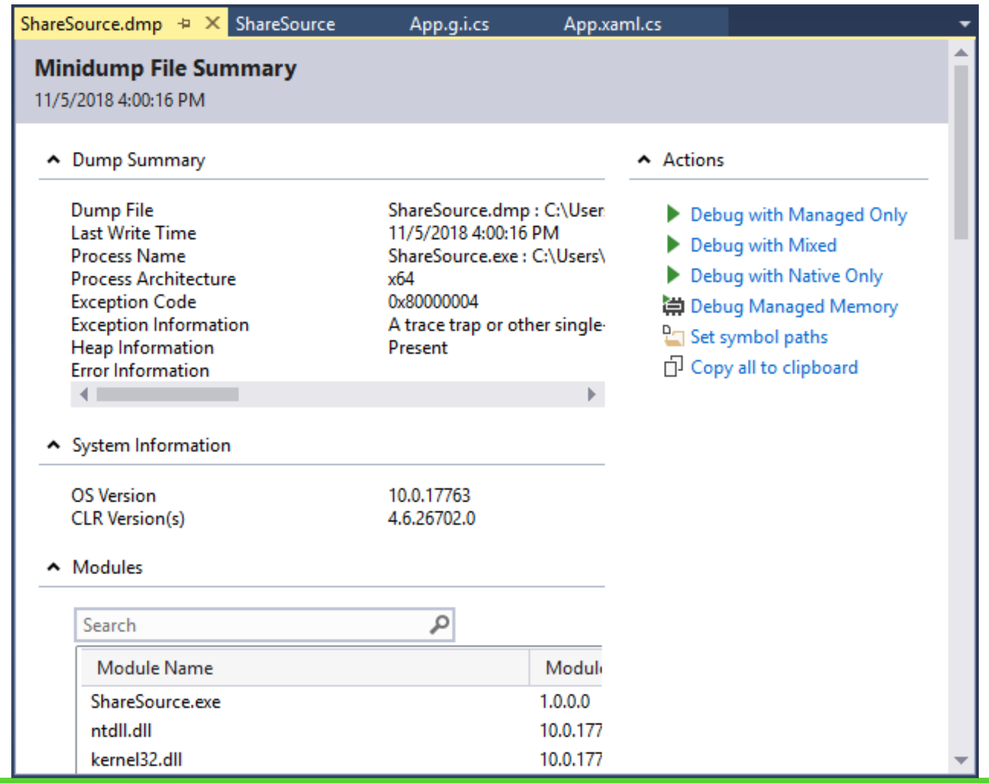
Game changer!

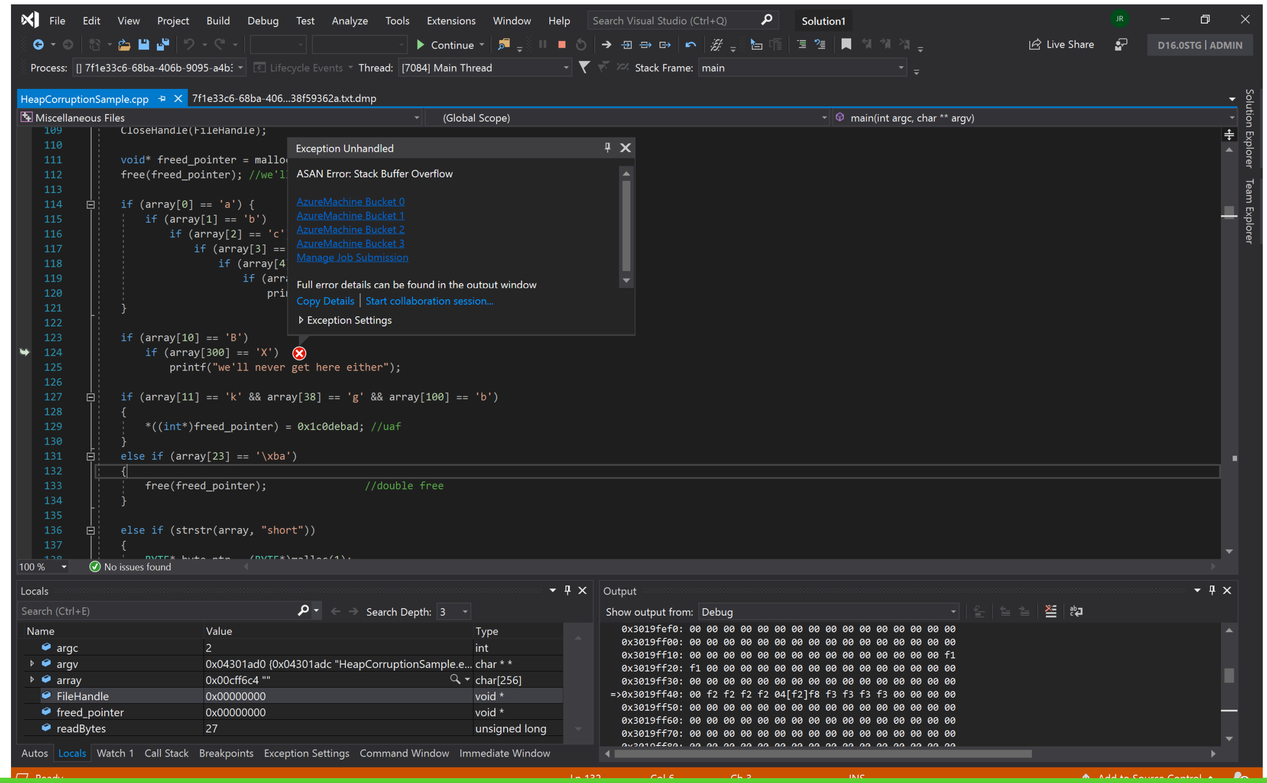
Minidump file (*.dmp) <= Windows snapshot process (program virtual memory/heap + metadata)

VS can parse & open this => Points at the location the error occurred.

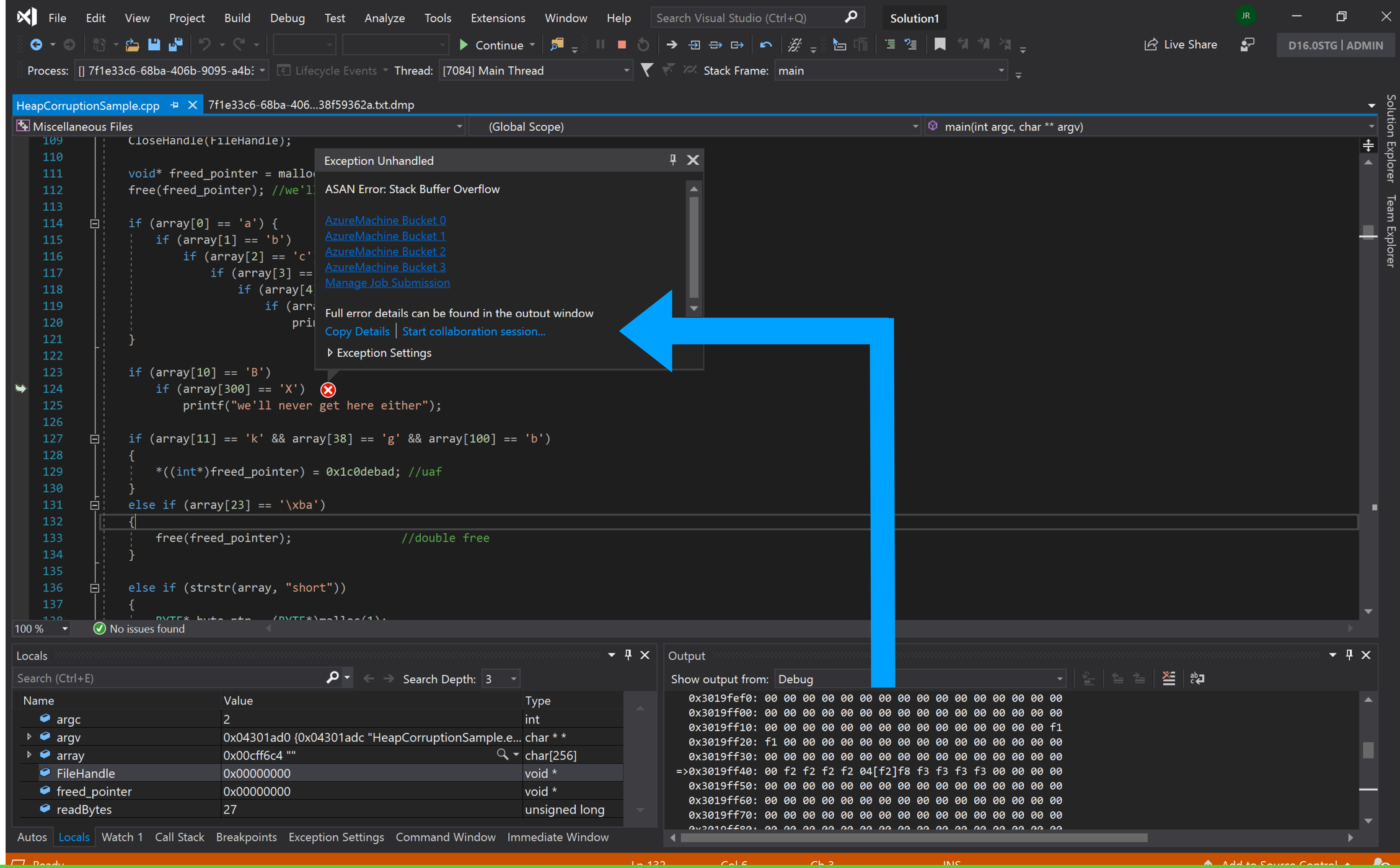
+ Live Share

Changes the way you report a bug, in general





Snapshot Loaded



How does it work ?

ASan is just Malware, used for Good 😈

Address Sanitizer (ASan)

Compiler

- instrumentation code, stack layout, and calls into runtime
- meta-data in OBJ for the runtime

Sanitizer Runtime

- hooking `malloc()`, `free()`, `memset()`, etc.
- error analysis and reporting
- does not require complete recompile => great for **interop**
- zero false positives

ASan Report

```
==23364==ERROR: AddressSanitizer: heap-buffer-overflow on address 0x12ac01b801d0 at
pc 0x7ff6e3a627be bp 0x0097d4b4fac0 sp 0x0097d4b4fac8
WRITE of size 4 at 0x12ac01b801d0 thread T0
#0 0x7ff6e3a627bd in main C:\Asana\Asana.cpp:10
#1 0x7ff6e3a66ce8 in invoke_main D:\agent\_work\9\s\src\vctools\crt\vcstartup\src\startup\exe_common.inl:78
#2 0x7ff6e3a66bcd in __scrt_common_main_seh D:\agent\_work\9\s\src\vctools\crt\vcstartup\src\startup\exe_common.inl:288
#3 0x7ff6e3a66a8d in __scrt_common_main D:\agent\_work\9\s\src\vctools\crt\vcstartup\src\startup\exe_common.inl:330
#4 0x7ff6e3a66d78 in mainCRTStartup D:\agent\_work\9\s\src\vctools\crt\vcstartup\src\startup\exe_main.cpp:16
#5 0x7ffee9a76fd3 in BaseThreadInitThunk+0x13 (C:\WINDOWS\System32\KERNEL32.DLL+0x180016fd3)
#6 0x7ffeea97cec0 in RtlUserThreadStart+0x20 (C:\WINDOWS\SYSTEM32\ntdll.dll+0x18004cec0)

0x12ac01b801d0 is located 0 bytes to the right of 400-byte region [0x12ac01b80040,0x12ac01b801d0)
allocated by thread T0 here:
#0 0x7ffe83be7e91 in _asan_loadN_noabort+0x55555 (...\bin\HostX64\x64\clang_rt.asan_dbg_dynamic-x86_64.dll+0x180057e91)
#1 0x7ff6e3a62758 in main C:\Asana\Asana.cpp:9
#2 0x7ff6e3a66ce8 in invoke_main D:\agent\_work\9\s\src\vctools\crt\vcstartup\src\startup\exe_common.inl:78
#3 0x7ff6e3a66bcd in __scrt_common_main_seh D:\agent\_work\9\s\src\vctools\crt\vcstartup\src\startup\exe_common.inl:288
#4 0x7ff6e3a66a8d in __scrt_common_main D:\agent\_work\9\s\src\vctools\crt\vcstartup\src\startup\exe_common.inl:330
#5 0x7ff6e3a66d78 in mainCRTStartup D:\agent\_work\9\s\src\vctools\crt\vcstartup\src\startup\exe_main.cpp:16
#6 0x7ffee9a76fd3 in BaseThreadInitThunk+0x13 (C:\WINDOWS\System32\KERNEL32.DLL+0x180016fd3)
#7 0x7ffeea97cec0 in RtlUserThreadStart+0x20 (C:\WINDOWS\SYSTEM32\ntdll.dll+0x18004cec0)
```

```
SUMMARY: AddressSanitizer: heap-buffer-overflow C:\Asana\Asana.cpp:10 in main()

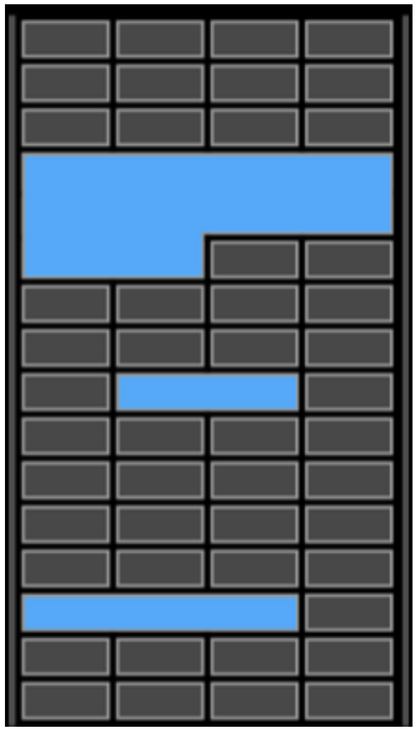
Shadow bytes around the buggy address:
  0x04d981eeffe0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x04d981eefff0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x04d981ef0000: fa fa fa fa fa fa fa fa 00 00 00 00 00 00 00 00
  0x04d981ef0010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x04d981ef0020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=>0x04d981ef0030: 00 00 00 00 00 00 00 00 00 00[fa]fa fa fa fa fa
  0x04d981ef0040: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x04d981ef0050: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x04d981ef0060: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x04d981ef0070: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x04d981ef0080: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
```

Addressable:	00 👍	
Partially addressable:	01 02 03 04 05 06 07	(of the 8 application bytes, how many are accessible)
Heap left redzone:	fa	
Freed heap region:	fd	
Stack left redzone:	f1	
Stack mid redzone:	f2	
Stack right redzone:	f3	
Stack after return:	f5	
Stack use after scope:	f8	
Global redzone:	f9	issues & markers
Global init order:	f6	
Poisoned by user:	f7	
Container overflow:	fc	
Array cookie:	ac	
Intra object redzone:	bb	
ASan internal:	fe	
Left alloca redzone:	ca	
Right alloca redzone:	cb	
Shadow gap:	cc	

Shadow byte legend

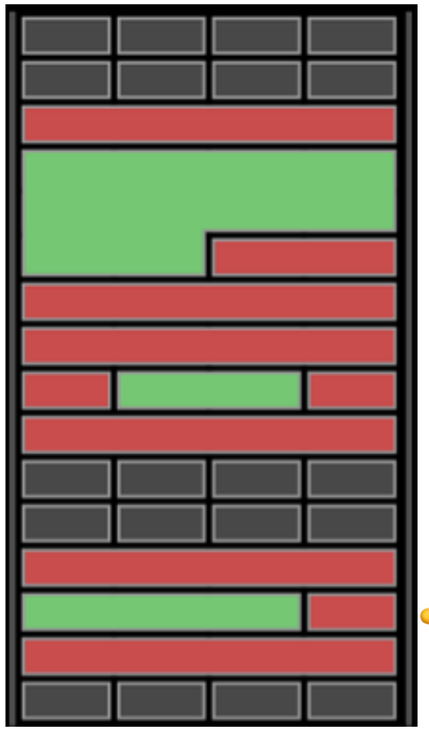
(one shadow byte represents 8 application bytes)

Shadow Mapping



my allocated memory

➡️



Process Memory

Shadow Memory

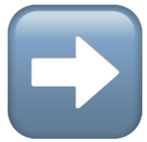
🧪☣️

Poisoned memory

👉 Red zones

Code Generation
(simplified)

```
*p = 0xbadf00d
```



```
if (ShadowByte::IsBad(p))
  AsanRt::Report(p, sz)

*p = 0xbadf00d
```

If the shadow byte is poisoned,

ASAN runtime **reports** the problem and **crashes** the application

Code Generation
(simplified)

Lookups into shadow memory need to be very fast

ASAN maintains a lookup table where every **8 bytes** of user memory are tracked by **1 shadow byte**

=> **1/8** of the address space (shadow region)

A Shadow Byte: `*( (User_Address >> 3) + 0x30000000 ) = 0xF8;`

Code Generation
(simplified)

Lookups into shadow memory need to be very fast

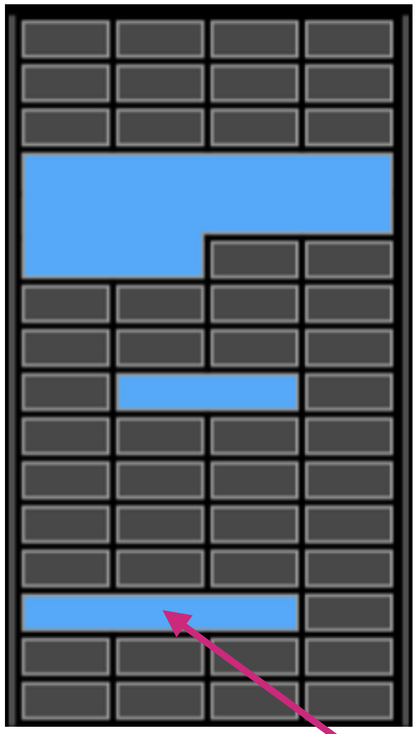
```
bool ShadowByte::IsBad(Addr) // is poisoned ?
{
  Shadow = Addr >> 3 + Offset;
  return (*Shadow) != 0;
}
```

Location of shadow region in memory

A Shadow Byte: `*( (User_Address >> 3) + 0x30000000 ) = 0xF8;`

Stack use after scope

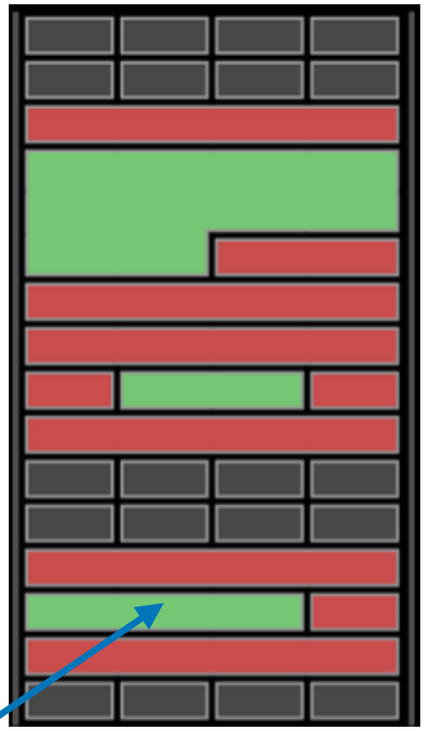
Shadow Mapping



Process Memory

```
if (ShadowByte::IsBad(p))
  AsanRt::Report(p, sz);

*p = 0xf00d
```

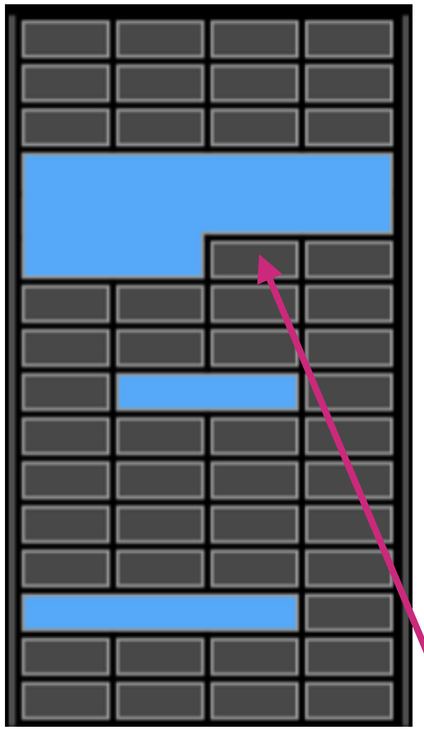


Shadow Memory

p

ShadowByte(p)

Shadow Mapping



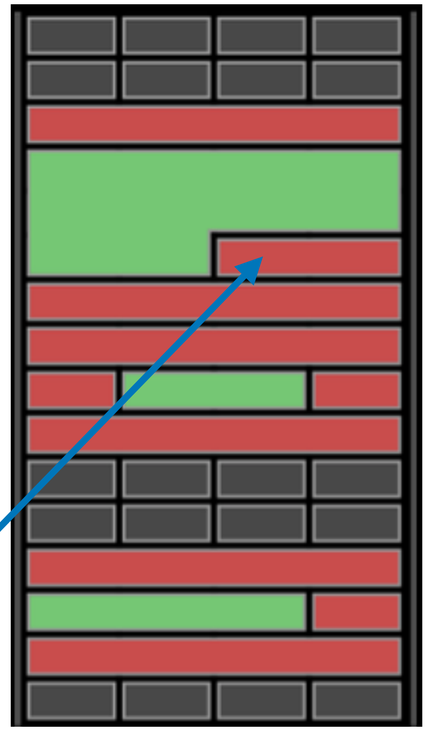
Process Memory

```
if (ShadowByte::IsBad(p))
  AsanRt::Report(p, sz);

*p = 0xbadf00d
```

p

ShadowByte(p)



Shadow Memory

Heap Red Zones

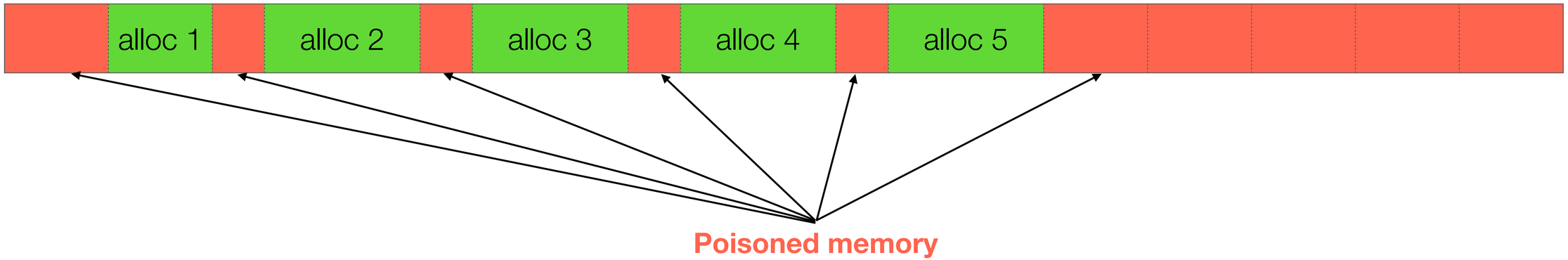
`malloc()`

`ASAN malloc()`

Heap Red Zones

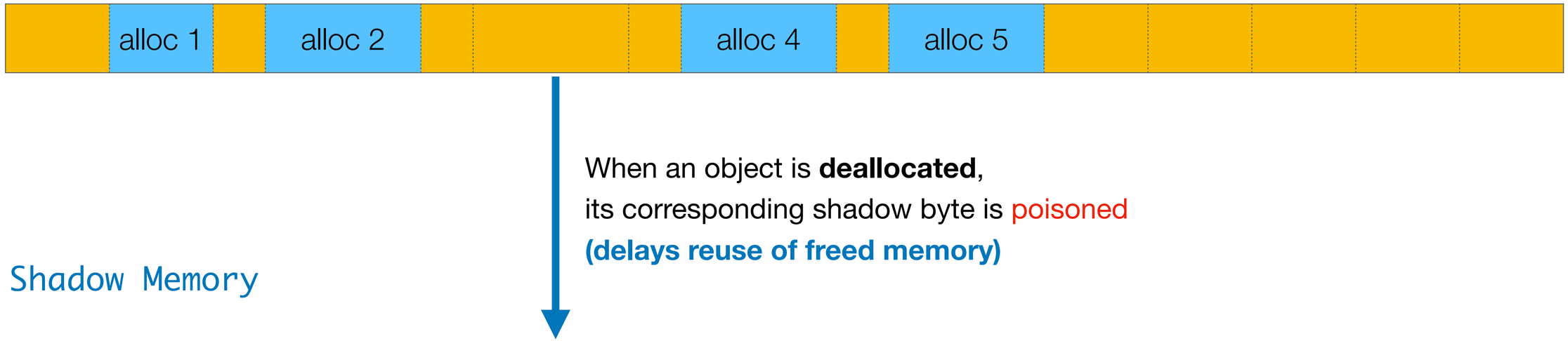
ASAN malloc()

Shadow Memory



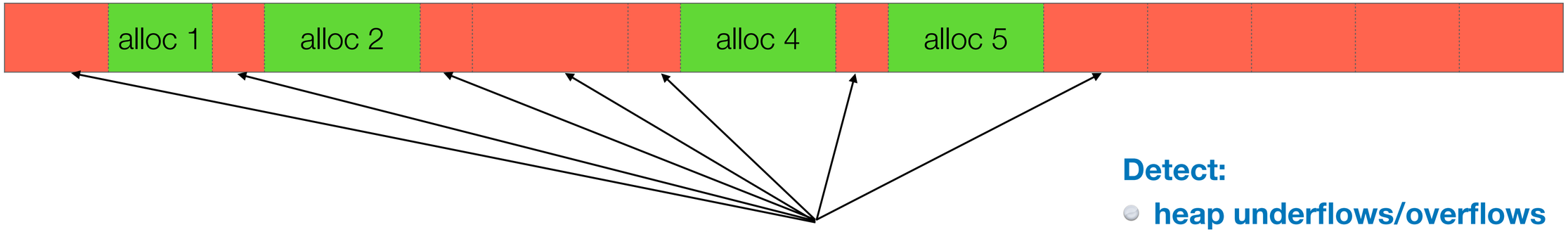
Heap Red Zones

ASAN malloc()



When an object is **deallocated**,
its corresponding shadow byte is poisoned
(delays reuse of freed memory)

Shadow Memory

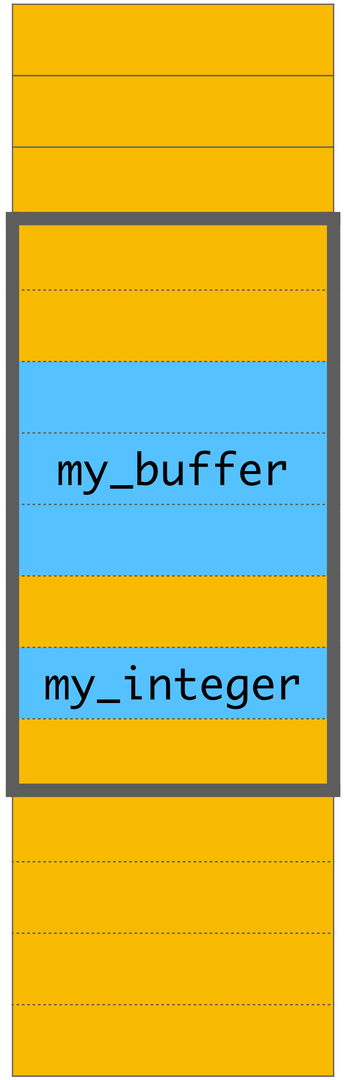


Poisoned memory

Detect:

- **heap underflows/overflows**
- **use-after-free & double free**

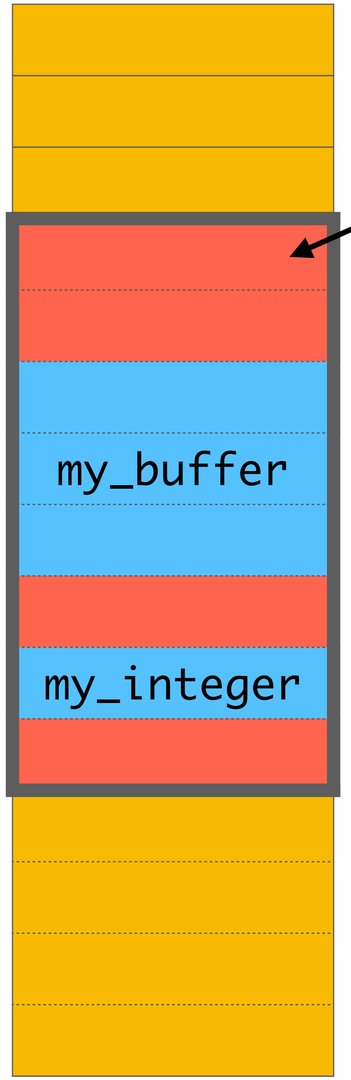
Stack Red Zones



Stack

```
void Func()
{
  std::byte my_buffer[12];
  int my_integer = 5;
  ...
  ...
  ...
  ...
  my_buffer[12] = 0;
}
```

Stack Red Zones



at runtime, the stack is **poisoned** when entering the function

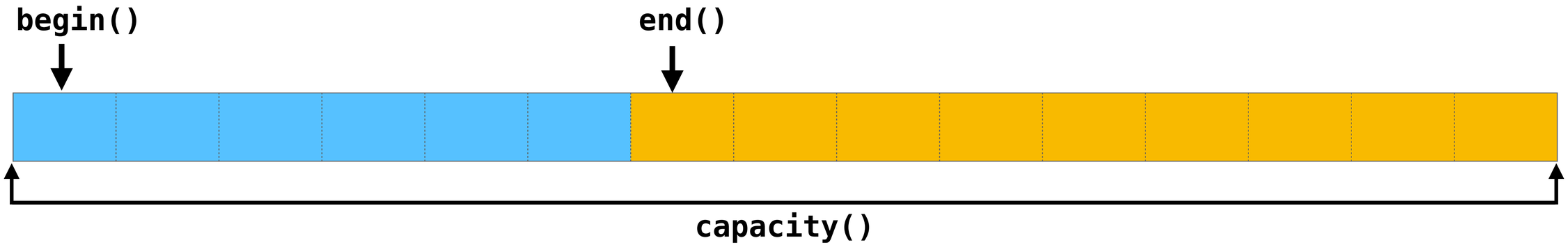
```
void Func()
{
  std::byte my_buffer[12];
  int my_integer = 5;
  ...

  if (AsanRt::IsPoisoned(&my_buffer[12]))
    AsanRt::Report(my_buffer);
  my_buffer[12] = 0;
}
```

stack red zones are **un-poisoned** when exiting the function

AddressSanitizer ContainerOverflow

`std::vector<T>`



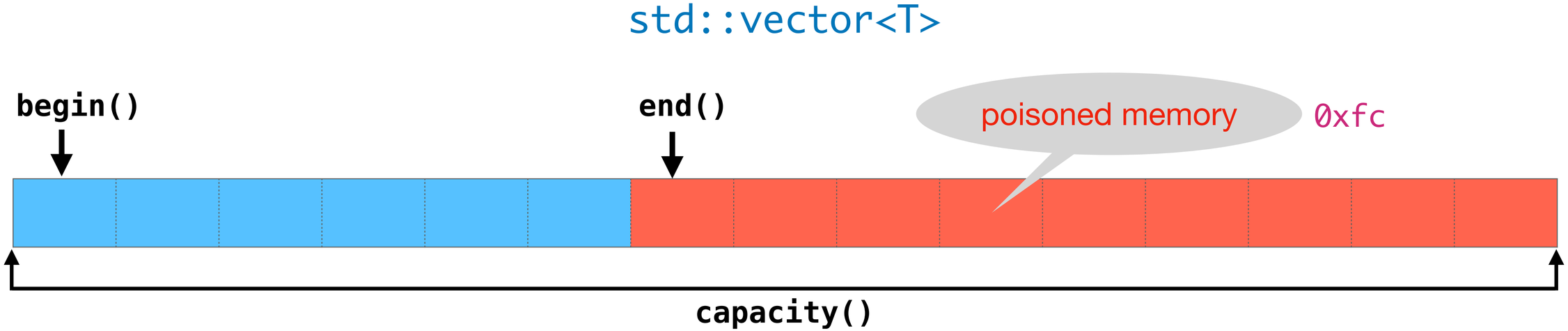
with the help of **code annotations** in **std::vector**

`libc++`

`libstdc++`

https://github.com/google/sanitizers/wiki/AddressSanitizerContainerOverflow

AddressSanitizer ContainerOverflow




```
std::vector<int> v;
v.push_back(0);
v.push_back(1);
v.push_back(2);
assert(v.capacity() >= 4);
assert(v.size() == 3);

T * p = &v[0];
std::cout << p[3];
```

container-overflow

0xfc

`v[3]` could be detected by simple checks in `std::vector`

https://github.com/google/sanitizers/wiki/AddressSanitizerContainerOverflow

Address Sanitizer (ASan)

Very fast instrumentation

The average slowdown of the instrumented program is ~2x

github.com/google/sanitizers/wiki/AddressSanitizerPerformanceNumbers

Problems & Gotchas

Stuff you need to know

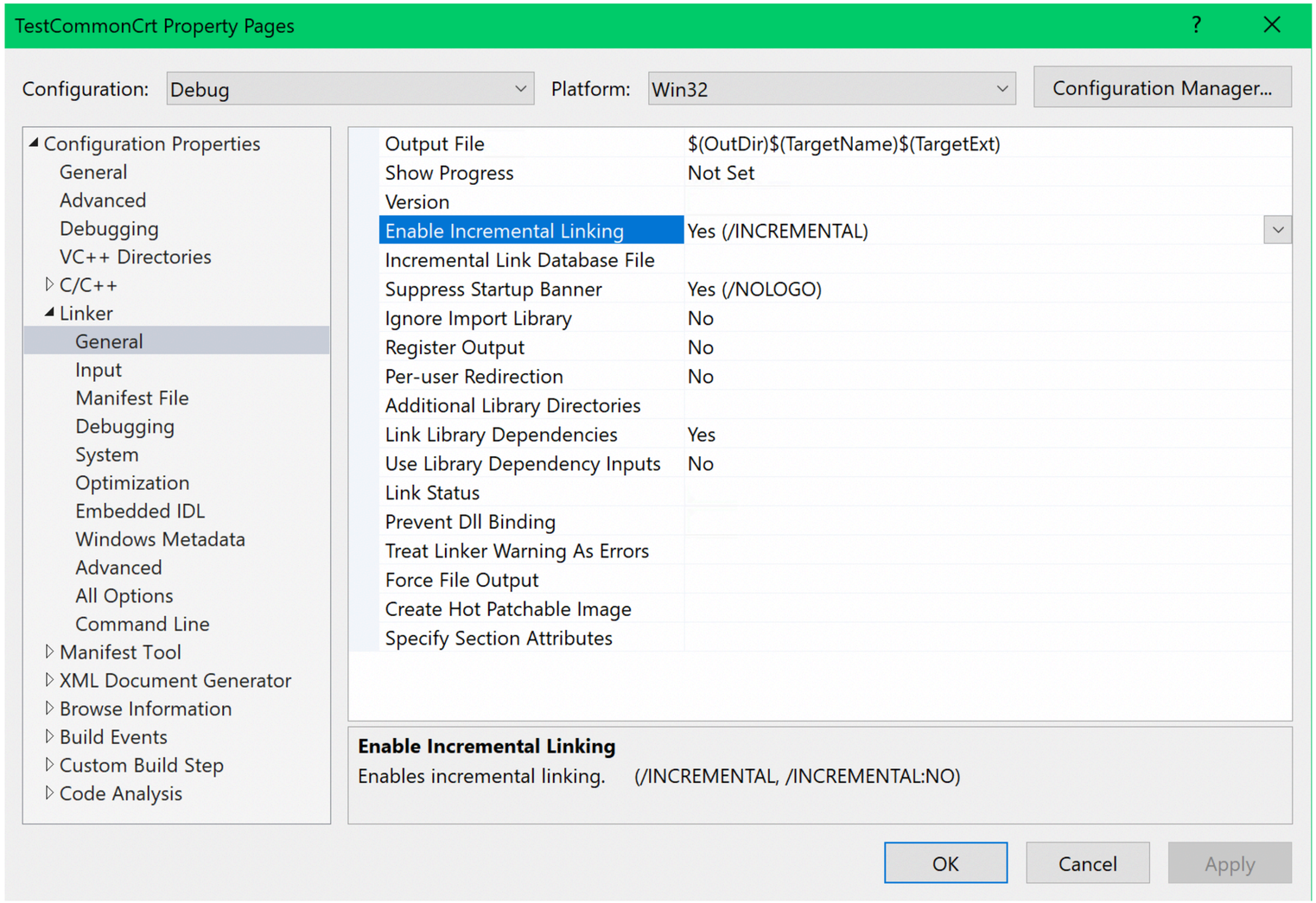
/ZI
Edit and Continue (Debug)

```
error MSB8059:

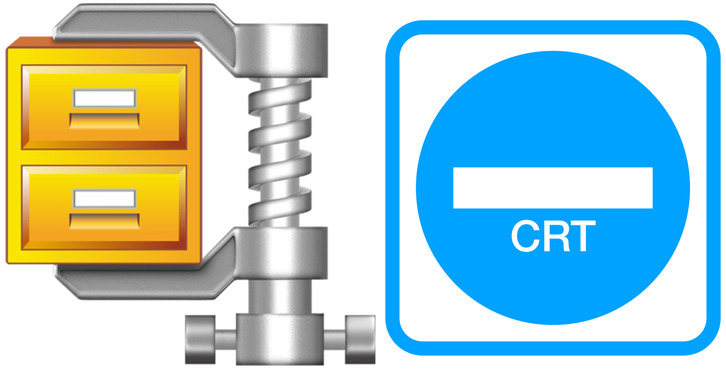
-fsanitize=address (Enable Address Sanitizer) is incompatible with option
'edit-and-continue' debug information /ZI
```

Link /INCREMENTAL

Debug builds

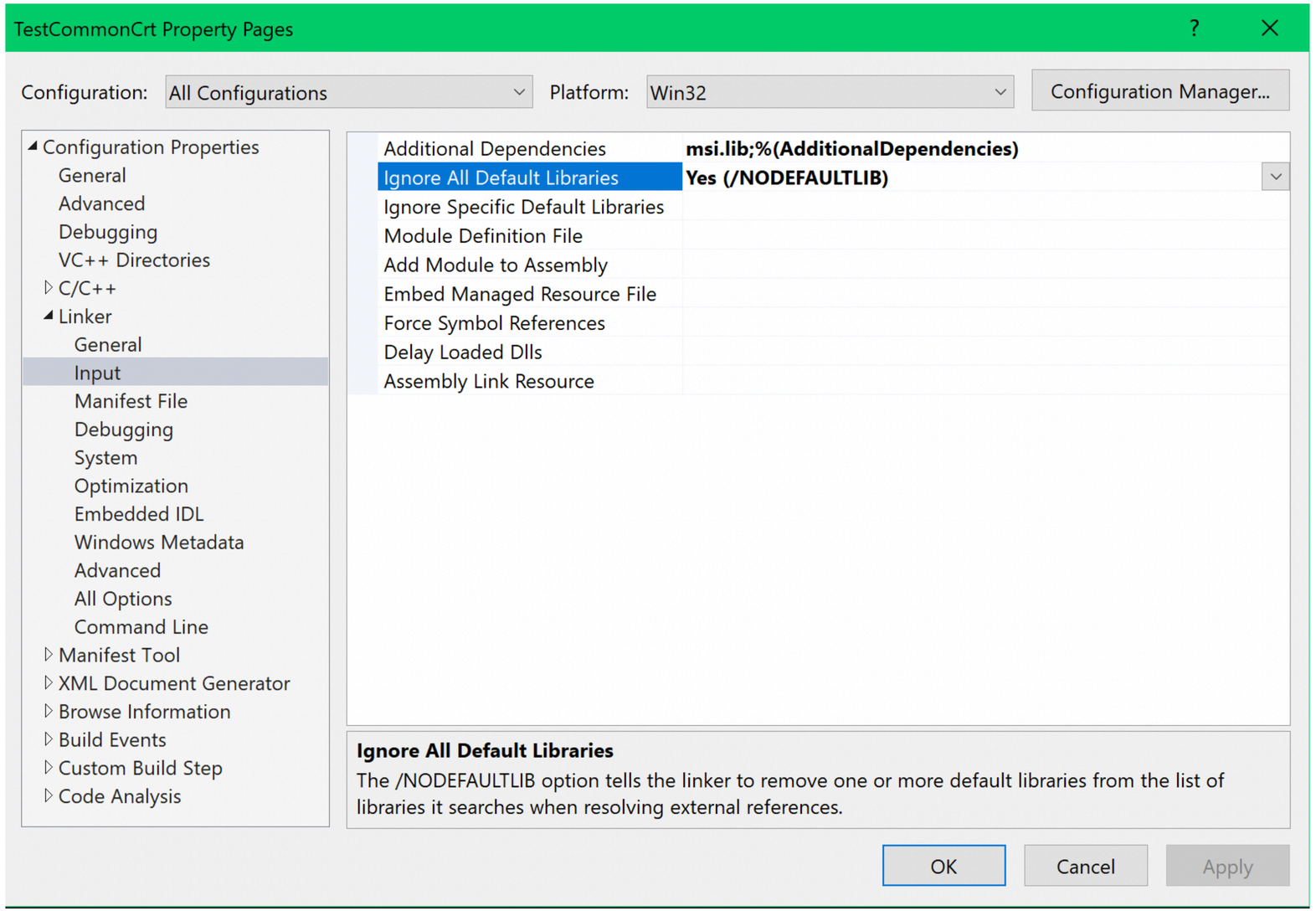


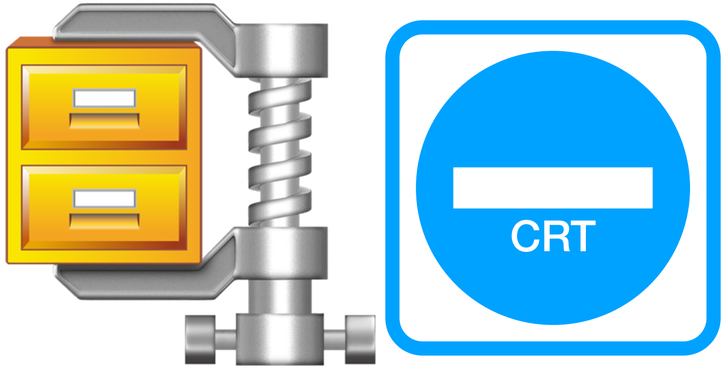

```
error MSB8059:
-fsanitize=address (Enable Address Sanitizer) is incompatible with option
'incremental linking (/INCREMENTAL)'
```



ASan + /NODEFAULTLIB

The linker will be very mad at you



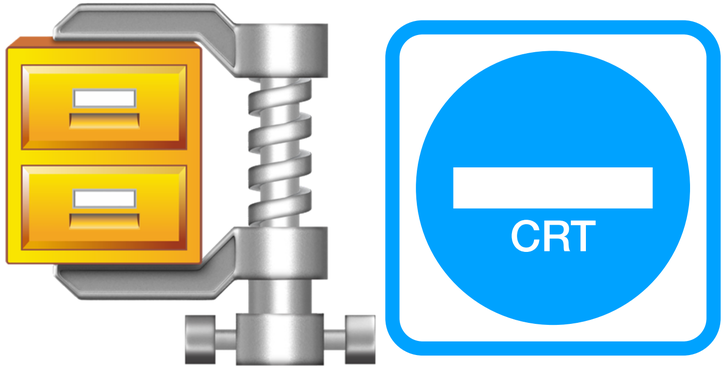


ASan + /NODEFAULTLIB

The linker will be very mad at you:

```
1>clang_rt.asan_dbg-i386.lib(ubsan_value.cc.obj) : error LNK2019: unresolved external symbol __allshl referenced in function "public: __int64 __thiscall __ubsan::Value::getSIntValue(void)const " (?getSIntValue@Value@__ubsan@@QBE_JXZ)
1>clang_rt.asan_dbg-i386.lib(ubsan_value.cc.obj) : error LNK2019: unresolved external symbol __allshr referenced in function "public: __int64 __thiscall __ubsan::Value::getSIntValue(void)const " (?getSIntValue@Value@__ubsan@@QBE_JXZ)
1>clang_rt.asan_dbg-i386.lib(ubsan_value.cc.obj) : error LNK2001: unresolved external symbol __fltused
1>clang_rt.asan_dbg-i386.lib(ubsan_diag.cc.obj) : error LNK2001: unresolved external symbol __fltused
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2001: unresolved external symbol __fltused
1>clang_rt.asan_dbg-i386.lib(asan_interceptors.cc.obj) : error LNK2001: unresolved external symbol __fltused
1>clang_rt.asan_dbg-i386.lib(ubsan_flags.cc.obj) : error LNK2019: unresolved external symbol _getenv referenced in function "char const * __cdecl __ubsan::GetFlag(char const *)" (?GetFlag@__ubsan@@YAPBDPBD@Z)
1>clang_rt.asan_dbg-i386.lib(ubsan_diag.cc.obj) : error LNK2019: unresolved external symbol ___stdio_common_vsprintf_s referenced in function _sprintf_s
1>clang_rt.asan_dbg-i386.lib(sanitizer_unwind_win.cc.obj) : error LNK2019: unresolved external symbol _memset referenced in function "private: void __thiscall __sanitizer::BufferedStackTrace::UnwindSlow(unsigned long,void *,unsigned int)
1>clang_rt.asan_dbg-i386.lib(interception_win.cc.obj) : error LNK2001: unresolved external symbol _memset
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2001: unresolved external symbol _memset
1>clang_rt.asan_dbg-i386.lib(asan_interceptors.cc.obj) : error LNK2001: unresolved external symbol _memset
1>clang_rt.asan_dbg-i386.lib(sanitizer_symbolizer_win.cc.obj) : error LNK2019: unresolved external symbol _wcsrchr referenced in function "void __cdecl __sanitizer::InitializeDbgHelpIfNeeded(void)" (?InitializeDbgHelpIfNeeded@__sanitizer
1>clang_rt.asan_dbg-i386.lib(sanitizer_symbolizer_win.cc.obj) : error LNK2019: unresolved external symbol _wcscat_s referenced in function "void __cdecl __sanitizer::InitializeDbgHelpIfNeeded(void)" (?InitializeDbgHelpIfNeeded@__sanitize
1>clang_rt.asan_dbg-i386.lib(sanitizer_allocator_checks.cc.obj) : error LNK2019: unresolved external symbol __errno referenced in function "void __cdecl __sanitizer::SetErrnoToENOMEM(void)" (?SetErrnoToENOMEM@__sanitizer@@YAXXZ)
1>clang_rt.asan_dbg-i386.lib(sanitizer_win.cc.obj) : error LNK2001: unresolved external symbol __errno
1>clang_rt.asan_dbg-i386.lib(asan_allocator.cc.obj) : error LNK2001: unresolved external symbol __errno
1>clang_rt.asan_dbg-i386.lib(sanitizer_win.cc.obj) : error LNK2019: unresolved external symbol _atexit referenced in function "int __cdecl __sanitizer::RunAtexit(void)" (?RunAtexit@__sanitizer@@YAHXZ)
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2001: unresolved external symbol _atexit
1>clang_rt.asan_dbg-i386.lib(sanitizer_win.cc.obj) : error LNK2019: unresolved external symbol _qsort referenced in function "void __cdecl __sanitizer::DumpProcessMap(void)" (?DumpProcessMap@__sanitizer@@YAXXZ)
1>clang_rt.asan_dbg-i386.lib(sanitizer_win.cc.obj) : error LNK2019: unresolved external symbol __alldiv referenced in function "unsigned __int64 __cdecl __sanitizer::NanoTime(void)" (?NanoTime@__sanitizer@@YA_KXZ)
1>clang_rt.asan_dbg-i386.lib(sanitizer_win.cc.obj) : error LNK2019: unresolved external symbol __allmul referenced in function "unsigned __int64 __cdecl __sanitizer::NanoTime(void)" (?NanoTime@__sanitizer@@YA_KXZ)
1>clang_rt.asan_dbg-i386.lib(sanitizer_win.cc.obj) : error LNK2019: unresolved external symbol __chkstk referenced in function "public: void __thiscall __sanitizer::ListOfModules::init(void)" (?init@ListOfModules@__sanitizer@@QAEXXZ)
1>clang_rt.asan_dbg-i386.lib(sanitizer_printf.cc.obj) : error LNK2019: unresolved external symbol __aulldvrm referenced in function "int __cdecl __sanitizer::AppendNumber(char * *,char const *,unsigned __int64,unsigned char,unsigned char
1>clang_rt.asan_dbg-i386.lib(interception_win.cc.obj) : error LNK2019: unresolved external symbol __stricmp referenced in function "bool __cdecl __interception::OverrideImportedFunction(char const *,char const *,char const *,unsigned lon
1>clang_rt.asan_dbg-i386.lib(asan_win.cc.obj) : error LNK2019: unresolved external symbol __except_handler3 referenced in function "void __cdecl __asan::InitializePlatformInterceptors(void)" (?InitializePlatformInterceptors@__asan@@YAXXZ
1>clang_rt.asan_dbg-i386.lib(asan_win.cc.obj) : error LNK2019: unresolved external symbol __except_handler4 referenced in function "void __cdecl __asan::InitializePlatformInterceptors(void)" (?InitializePlatformInterceptors@__asan@@YAXXZ
1>libvcasand.lib(vcasan.obj) : error LNK2001: unresolved external symbol __except_handler4
1>clang_rt.asan_dbg-i386.lib(asan_win.cc.obj) : error LNK2019: unresolved external symbol __tls_array referenced in function "void * __cdecl __asan::AsanTSDGet(void)" (?AsanTSDGet@__asan@@YAPAXXZ)
1>clang_rt.asan_dbg-i386.lib(asan_win.cc.obj) : error LNK2019: unresolved external symbol __tls_index referenced in function "void * __cdecl __asan::AsanTSDGet(void)" (?AsanTSDGet@__asan@@YAPAXXZ)
1>clang_rt.asan_dbg-i386.lib(asan_rtl.cc.obj) : error LNK2019: unresolved external symbol __aullrem referenced in function "void __cdecl __asan::InitializeHighMemEnd(void)" (?InitializeHighMemEnd@__asan@@YAXXZ)
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol __invalid_parameter referenced in function "void * __cdecl std::_Allocate_manually_vector_aligned<struct std::_Default_allocate_tra
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol __CrtDbgReport referenced in function "void * __cdecl std::_Allocate_manually_vector_aligned<struct std::_Default_allocate_traits>(
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol "public: __thiscall std::_Lockit::_Lockit(int)" (??0_Lockit@std@@QAE@H@Z) referenced in function "public: __thiscall std::_List_ite
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol "public: __thiscall std::_Lockit::~_Lockit(void)" (??1_Lockit@std@@QAE@XZ) referenced in function "public: __thiscall std::_List_it
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol ___std_exception_copy referenced in function "public: __thiscall std::bad_alloc::bad_alloc(class std::bad_alloc const &)" (??0bad_a
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol ___std_exception_destroy referenced in function "public: virtual __thiscall std::bad_array_new_length::~bad_array_new_length(void)"
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol "void __cdecl std::_Xlength_error(char const *)" (?_Xlength_error@std@@YAXPBD@Z) referenced in function "protected: struct std::pa
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol "void __cdecl std::_Xout_of_range(char const *)" (?_Xout_of_range@std@@YAXPBD@Z) referenced in function "public: void * __thiscall
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol __Mtx_init_in_situ referenced in function "void __cdecl `dynamic initializer for 'GlobalHeapMutex''(void)" (??__EGlobalHeapMutex@@
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol __Mtx_destroy_in_situ referenced in function "void __cdecl `dynamic atexit destructor for 'GlobalHeapMutex''(void)" (??__FGlobalHea
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol __Mtx_lock referenced in function "public: void * __thiscall MoveableMemoryManager::Alloc(unsigned long,unsigned int)" (?Alloc@Move
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol __Mtx_unlock referenced in function "public: void * __thiscall MoveableMemoryManager::Alloc(unsigned long,unsigned int)" (?Alloc@Mo
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol "void __cdecl std::_Throw_C_error(int)" (?_Throw_C_error@std@@YAXH@Z) referenced in function "public: void * __thiscall MoveableMem
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol __CxxThrowException@8 referenced in function __catch$??$_Emplace_reallocate@ABQAVMoveableAllocEntry@@@?$vector@PAVMoveableAllocEnt
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol ___CxxFrameHandler3 referenced in function __ehhandler$??$_Emplace_reallocate@ABQAVMoveableAllocEntry@@@?$vector@PAVMoveableAllocEn
1>libvcasand.lib(vcasan.obj) : error LNK2001: unresolved external symbol ___CxxFrameHandler3
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol __ftoui3 referenced in function "protected: struct std::pair<struct std::_List_node<struct std::pair<void * const,class MoveableAll
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol _ceil referenced in function "protected: struct std::pair<struct std::_List_node<struct std::pair<void * const,class MoveableAlloc
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol _memcpy referenced in function "public: void * __thiscall MoveableMemoryManager::ReallocFixedToHandle(void *,bool)" (?ReallocFixed
1>clang_rt.asan_dbg-i386.lib(asan_interceptors.cc.obj) : error LNK2001: unresolved external symbol _memcpy
1>libvcasand.lib(vcasan.obj) : error LNK2001: unresolved external symbol _memcpy
1>clang_rt.asan_dbg-i386.lib(asan_malloc_win_moveable.cc.obj) : error LNK2019: unresolved external symbol _memmove referenced in function "class MoveableAllocEntry * * * __cdecl std::_Copy_memmove<class MoveableAllocEntry * * *,class Mo
```

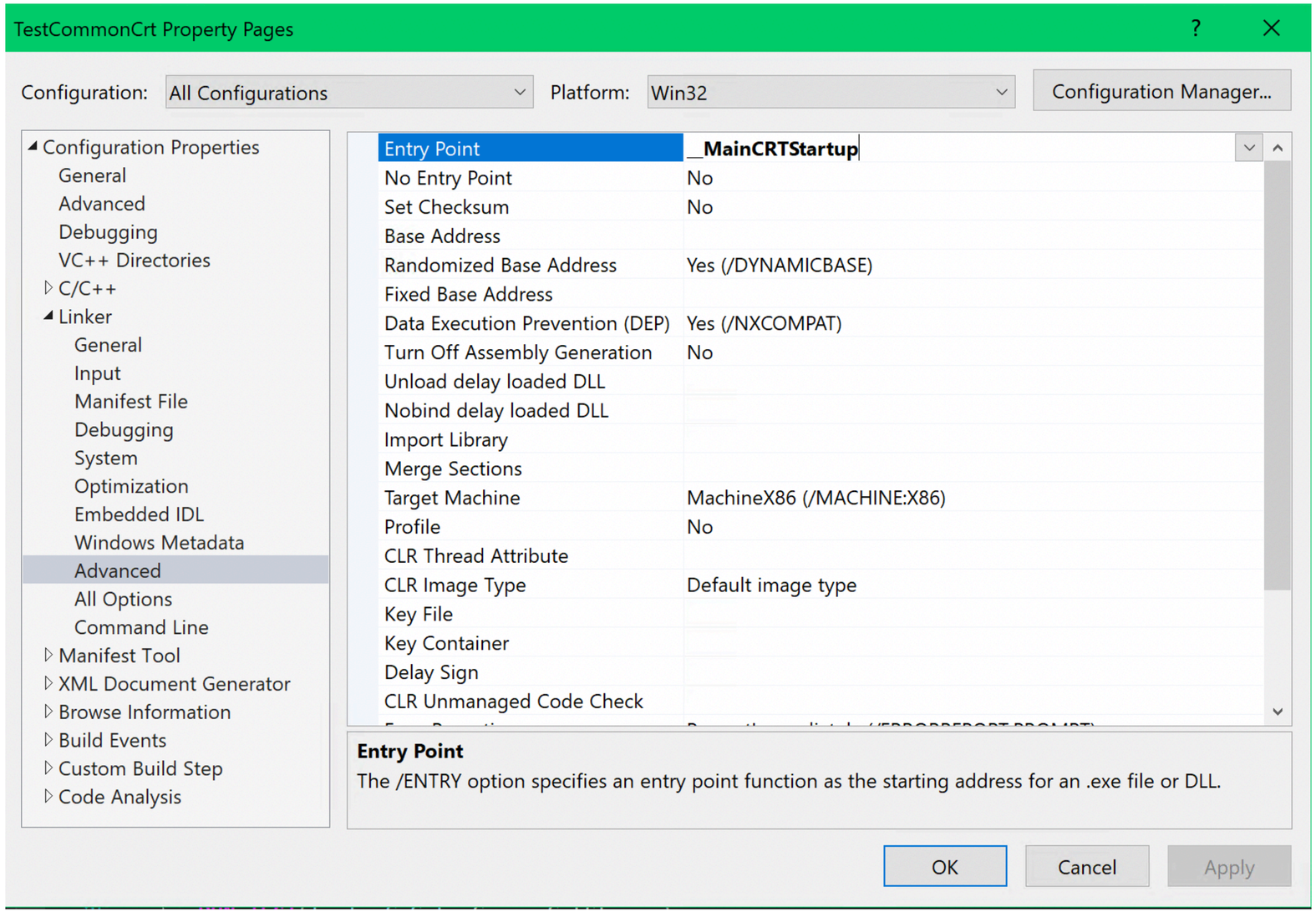
ASan runtime assumes **CRT** is linked



ASan + /NODEFAULTLIB

The linker will be very mad at you

if you have a custom entry point
(bypass CRT main)



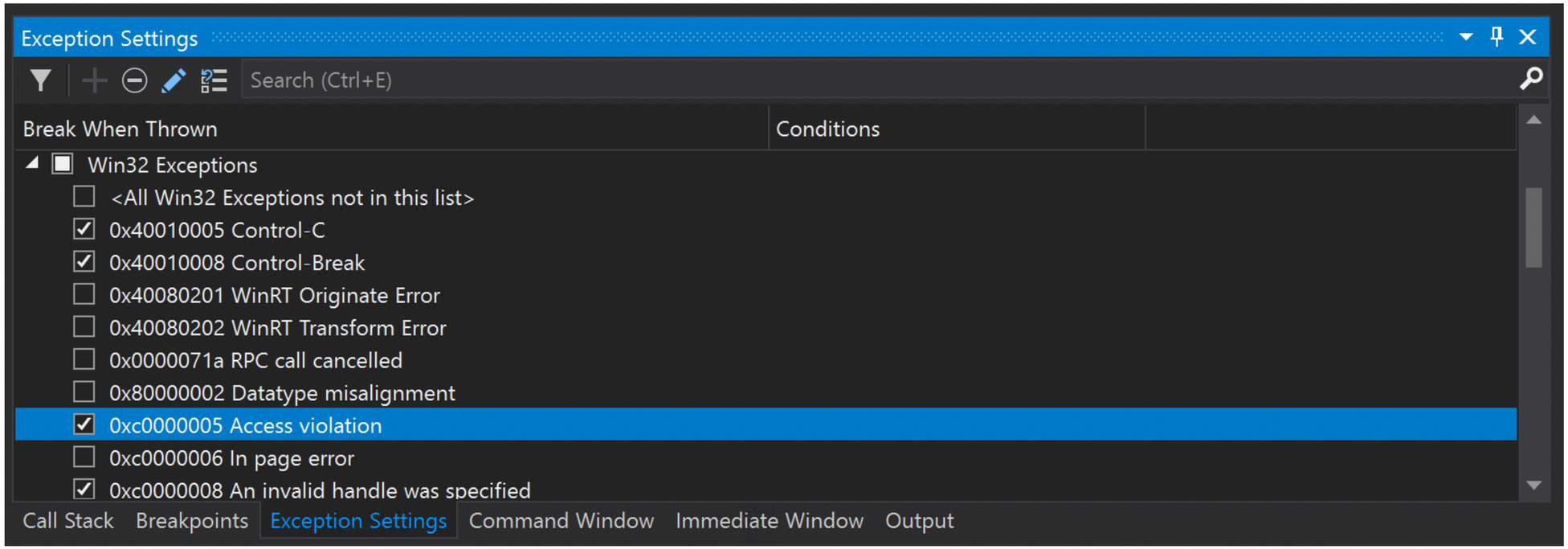
Access Violation Exceptions

Debugger may break frequently and you may see a lot of SEH access violation exceptions

This is normal (x64). It's how ASAN traps memory allocations to instrument its own *shadow memory*

Just tell the *Debugger* to stop breaking on this type of exception:

uncheck 👉



Mixing ASan & non-ASan modules

Problem:

A non-ASan built executable can NOT call `LoadLibrary()` on a DLL built with ASAN.

Reason:

ASan runtime is tracking memory and the non-ASan executable might have done something like `HeapAlloc()`

This limitation is a problem if you're building a plugin (DLL)

MSVC team is considering dealing with this issue in a later release

devblogs.microsoft.com/cppblog/asan-for-windows-x64-and-debug-build-support/

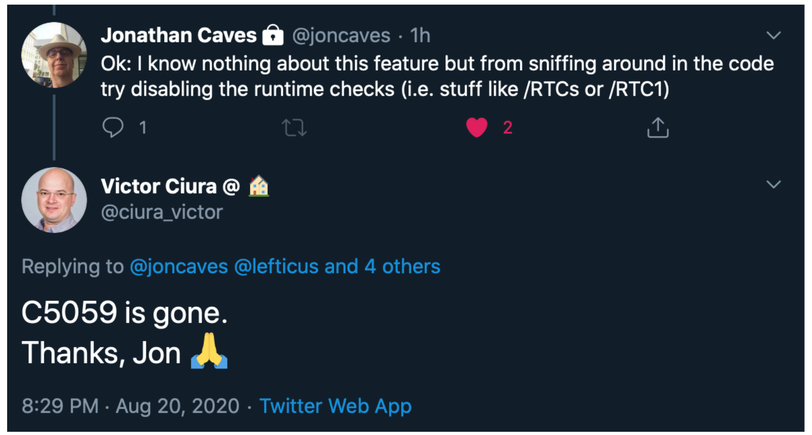
/RTCs and /RTC1 Runtime Checks

`warning C5059:`

runtime checks and address sanitizer is not currently supported - disabling runtime checks

If you use **`/WX`** this harmless/informative warning becomes a build blocker **:(**

=> we had to disable `/RTCs` and `/RTC1` so we could do the ASan experiments



twitter.com/ciura_victor/status/1296499633825492992

Linker Trouble?

Building a static LIB, linked into an EXE

```
[Debug | x64]
>libucrtd.lib(debug_heap.obj) : warning LNK4006: _calloc_dbg already defined in clang_rt.asan_dbg-x86_64.lib(asan_malloc_win.cc.obj); second definition ignored
>libucrtd.lib(debug_heap.obj) : warning LNK4006: _expand_dbg already defined in clang_rt.asan_dbg-x86_64.lib(asan_malloc_win.cc.obj); second definition ignored
>libucrtd.lib(debug_heap.obj) : warning LNK4006: _free_dbg already defined in clang_rt.asan_dbg-x86_64.lib(asan_malloc_win.cc.obj); second definition ignored
>libucrtd.lib(debug_heap.obj) : warning LNK4006: _malloc_dbg already defined in clang_rt.asan_dbg-x86_64.lib(asan_malloc_win.cc.obj); second definition ignored
>libucrtd.lib(debug_heap.obj) : warning LNK4006: _realloc_dbg already defined in clang_rt.asan_dbg-x86_64.lib(asan_malloc_win.cc.obj); second definition ignored
>libucrtd.lib(debug_heap.obj) : warning LNK4006: _recalloc_dbg already defined in clang_rt.asan_dbg-x86_64.lib(asan_malloc_win.cc.obj); second definition ignored
>libucrtd.lib(expand.obj)     : warning LNK4006: _expand already defined in clang_rt.asan_dbg-x86_64.lib(asan_malloc_win.cc.obj); second definition ignored
```

```
[Debug | x86]
>libucrtd.lib(debug_heap.obj) : warning LNK4006: __calloc_dbg already defined in clang_rt.asan_dbg-i386.lib(asan_malloc_win.cc.obj); second definition ignored
>libucrtd.lib(debug_heap.obj) : warning LNK4006: __expand_dbg already defined in clang_rt.asan_dbg-i386.lib(asan_malloc_win.cc.obj); second definition ignored
>libucrtd.lib(debug_heap.obj) : warning LNK4006: __free_dbg already defined in clang_rt.asan_dbg-i386.lib(asan_malloc_win.cc.obj); second definition ignored
>libucrtd.lib(debug_heap.obj) : warning LNK4006: __malloc_dbg already defined in clang_rt.asan_dbg-i386.lib(asan_malloc_win.cc.obj); second definition ignored
>libucrtd.lib(debug_heap.obj) : warning LNK4006: __realloc_dbg already defined in clang_rt.asan_dbg-i386.lib(asan_malloc_win.cc.obj); second definition ignored
>libucrtd.lib(debug_heap.obj) : warning LNK4006: __recalloc_dbg already defined in clang_rt.asan_dbg-i386.lib(asan_malloc_win.cc.obj); second definition ignored
>libucrtd.lib(expand.obj)     : warning LNK4006: __expand already defined in clang_rt.asan_dbg-i386.lib(asan_malloc_win.cc.obj); second definition ignored
```

+ ASan

```
>uafxcw.lib(afxmem.obj) : error LNK2005: "void * __cdecl operator new(unsigned int)" (??2@YAPAXI@Z) already
defined in clang_rt.asan_cxx-i386.lib(asan_new_delete.cc.obj)

>uafxcw.lib(afxmem.obj) : error LNK2005: "void __cdecl operator delete(void *)" (??3@YAXPAX@Z) already
defined in clang_rt.asan_cxx-i386.lib(asan_new_delete.cc.obj)

>uafxcw.lib(afxmem.obj) : error LNK2005: "void * __cdecl operator new[](unsigned int)" (??_U@YAPAXI@Z)
already defined in clang_rt.asan_cxx-i386.lib(asan_new_delete.cc.obj)

>uafxcw.lib(afxmem.obj) : error LNK2005: "void __cdecl operator delete[](void *)" (??_V@YAXPAX@Z) already
defined in clang_rt.asan_cxx-i386.lib(asan_new_delete.cc.obj)
```

⚠ **if you link statically to MFC lib**

developercommunity.visualstudio.com/content/problem/1144525/mfc-application-fails-to-link-with-address-sanitiz.html

+ ASan

In general, if you have overrides for:

```
void* operator new(size_t size);
```

Workarounds:

- set `/FORCE:MULTIPLE` in the linker command line (settings)
- temporarily set your MFC application to link to **shared** MFC DLLs for testing with ASan

ASAN Finds bugs

Really !

```
AddressSanitizer: heap-buffer-overflow on address 0x0a2301b4 pc 0x005b7a35 bp 0x011df078 sp 0x011df06c
READ of size 5 at 0x0a2301b4 thread T0

    #0 0x5b7a4d in __asan_wrap_strlen crt\asan\llvm\compiler-rt\lib\sanitizer_common\sanitizer_common_interceptors.inc:365
    #1 0x278eeb in ATL::CSimpleStringT<char,0>::StringLength MSVC\14.28.29333\atlmfc\include\atlsimpstr.h:726
    #2 0x278a35 in ATL::CSimpleStringT<char,0>::SetString MSVC\14.28.29333\atlmfc\include\atlsimpstr.h:602
    #3 0x274d69 in ATL::CSimpleStringT<char,0>::operator= MSVC\14.28.29333\atlmfc\include\atlsimpstr.h:314
    #4 0x274d99 in ATL::CStringT<char,ATL::StrTraitATL<char,ATL::ChTraitsCRT<char>>>::operator=
                   MSVC\14.28.29333\atlmfc\include\cstringt.h:1315
    #5 0x27469c in ATL::CStringT<char,ATL::StrTraitATL<char,ATL::ChTraitsCRT<char>>>::CStringT
                   MSVC\14.28.29333\atlmfc\include\cstringt.h:1115
    #6 0x27641a in SerValUtil::DecryptString C:\JobAI\advinst\msicomp\serval\SerValUtil.cpp:85
    #7 0x3e1660 in TestSerVal C:\JobAI\testunits\serval\SerValTests.cpp:60
    #8 0x5880e5 in FunctionTest::Run C:\JobAI\testunits\Tester.cpp:71
    #9 0x5889b1 in Tester::RunTest C:\JobAI\testunits\Tester.cpp:186
    #10 0x586ddb in Tester::ExecuteCommandLine C:\JobAI\testunits\Tester.cpp:558
    #11 0x5798d1 in main C:\JobAI\testunits\comps\TestComponents.cpp:2236

0x0a2301b4 is located 0 bytes to the right of 4-byte region [0x0a2301b0,0x0a2301b4)
allocated by thread T0
```

Fun with ATL::CString

```
ATL::CSimpleArray<BYTE> decrypted;
X::DecryptString(encrypted, decrypted);

ATL::CStringA decryptedStr(&decrypted[0]);
decryptedStr.ReleaseBufferSetLength(decrypted.GetSize());
```

Fun with ATL::CString

```
ATL::CSimpleArray<BYTE> decrypted;
X::DecryptString(encrypted, decrypted);

ATL::CStringA decryptedStr(&decrypted[0]);
decryptedStr.ReleaseBufferSetLength(decrypted.GetSize());
```

Fun with ATL::CString

Somewhere inside

```
ATL::CString::ReleaseBufferSetLength(int nLength)
{

   GetData()->nDataLength = nLength;
   m_pszData[nLength] = 0;
   ...
```

Fun with `ATL::CString`

Classic story: null-terminated string.

Array of chars to string class - size has a different meaning, because of the ending `\0`

Easy fix

```
ATL::CSimpleArray<BYTE> decrypted;
X::DecryptString(encrypted, decrypted);

ATL::CStringA decryptedStr(decrypted.GetData(), decrypted.GetSize());
```

It's actually more efficient, too.

```
AddressSanitizer: stack-buffer-overflow on address 0x00b3f766 at pc 0x00181b07 bp 0x00b3f6bc sp
0x00b3f6b0
WRITE of size 2 at 0x00b3f766 thread T0

    #0 0x181b06 in CommonCrt::ItoaT<wchar_t> C:\JobAI\platform\util\CommonCrt.h:402
    #1 0x183e02 in CommonCrt::Itoa C:\JobAI\platform\util\CommonCrt.cpp:119
    #2 0x190696 in TestCommonCrtItoa C:\JobAI\testunits\common_crt\CommonCrtTests.cpp:93
    #3 0x194821 in Tester::RunTest<int (__cdecl*)(void)> C:\JobAI\testunits\common_crt\tester\Tester.h:55
    #4 0x194b65 in main C:\JobAI\testunits\common_crt\main.cpp:22
    #5 0x1cc142 in invoke_main crt\vcstartup\src\startup\exe_common.inl:78
    #6 0x1cc046 in __scrt_common_main_seh crt\vcstartup\src\startup\exe_common.inl:288
    #7 0x1cbeec in __scrt_common_main crt\vcstartup\src\startup\exe_common.inl:330
    #8 0x1cc1a7 in mainCRTStartup crt\vcstartup\src\startup\exe_main.cpp:16
    #9 0x7645fa28 in BaseThreadInitThunk+0x18 (C:\WINDOWS\System32\KERNEL32.DLL+0x6b81fa28)
    #10 0x773e76b3 in RtlGetAppContainerNamedObjectPath+0xe3 (C:\WINDOWS\SYSTEM32\ntdll.dll+0x4b2e76b3)
    #11 0x773e7683 in RtlGetAppContainerNamedObjectPath+0xb3 (C:\WINDOWS\SYSTEM32\ntdll.dll+0x4b2e7683)

Address 0x00b3f766 is located in stack of thread T0 at offset 30 in frame
    #0 0x1905ef in TestCommonCrtItoa C:\JobAI\testunits\common_crt\CommonCrtTests.cpp:84

  This frame has 2 object(s):
    [16, 30) 'result1' <== Memory access at offset 30 overflows this variable
    [32, 46) 'result2' <== Memory access at offset 30 underflows this variable
```

Naive Test Unit

```
const LONG    kNumber1 = 21474835;
TCHAR         result1[kMaxSize];
const TCHAR * compare1 = L"21474835";
const LONG    kNumber2 = -2100;
TCHAR         result2[kMaxSize];
const TCHAR * compare2 = L"-2100";

CommonCrt::Itoa(kNumber1, result1);

ASSERT_EQ(CompareStrings(result1, compare1));
...
```

Naive Test Unit

```
const LONG    kNumber1 = 21474835;
TCHAR         result1[kMaxSize];
const TCHAR * compare1 = L"21474835";
const LONG    kNumber2 = -2100;
TCHAR         result2[kMaxSize];
const TCHAR * compare2 = L"-2100";

CommonCrt::Itoa(kNumber1, result1);

ASSERT_EQ(CompareStrings(result1, compare1));
...
```

```
AddressSanitizer: stack-buffer-overflow on address 0x00843b3ae544 at pc 0x7ff6da711d86 bp 0x00843b3ae180
sp 0x00843b3ae188
READ of size 1 at 0x00843b3ae544 thread T0

#0 0x7ff6da711d85 in std::_Char_traits<unsigned char,long>::length MSVC\14.28.29333\include\xstring:143
    #1 0x7ff6da711667 in std::basic_string<unsigned char,std::char_traits<unsigned char>,std::allocator<unsigned char> >::assign
                         MSVC\14.28.29333\include\xstring:3062
    #2 0x7ff6da70af94 in std::basic_string<unsigned char...> MSVC\14.28.29333\include\xstring:2417
    #3 0x7ff6da70c163 in TestStringUtilAsciiToUnicode C:\JobAI\testunits\strings\StringEncodingTests.cpp:26
    #4 0x7ff6da98db80 in FunctionTest::Run C:\JobAI\testunits\Tester.cpp:71
    #5 0x7ff6da98fb05 in Tester::RunTest C:\JobAI\testunits\Tester.cpp:186
    #6 0x7ff6da98b3b4 in Tester::ExecuteCommandLine C:\JobAI\testunits\Tester.cpp:558
    #7 0x7ff6da97b59e in main C:\JobAI\testunits\comps\TestComponents.cpp:2236
    #8 0x7ff6dac2a8d8 in invoke_main d:\agent\_work\63\s\src\vctools\crt\vcstartup\src\startup\exe_common.inl:78

Address 0x00843b3ae544 is located in stack of thread T0 at offset 564 in frame
    #0 0x7ff6da70badf in TestStringUtilAsciiToUnicode C:\JobAI\testunits\strings\StringEncodingTests.cpp:14

This frame has 12 object(s):
    [32, 72) 'result1'
    [48, 88) 'kTextString1'
    [64, 104) 'result2'
    [80, 120) 'kTextString3'
    [96, 136) 'result3'
    [112, 152) 'compiler temporary'
    [128, 144) 'compiler temporary'
    [144, 160) 'compiler temporary'
    [160, 164) 'uChars'
    [176, 177) 'compiler temporary'
    [192, 216) 'compiler temporary'
    [208, 232) 'compiler temporary' <== Memory access at offset 564 overflows this variable
```

Naive Test Unit

```
unsigned char                       uChars[] = { 0x41, 0x42, 0x43, 0x44 };
const basic_string<unsigned char> kTextString3(uChars);
wstring                             result3 = wstring(kTextString3.begin(), kTextString3.end());
if (StringUtil::AsciiToUnicode(kTextString3) ≠ result3)
  return -1;
```

Naive Test Unit

```
unsigned char                       uChars[] = { 0x41, 0x42, 0x43, 0x44 };
const basic_string<unsigned char> kTextString3(uChars);
wstring                             resu                                    );
if (StringUtil::AsciiToUnicode(kTextSt
  return -1;
return 0;
```

(local variable) const std::basic_string<unsigned char> kTextString3

Search Online

C6054: String 'uChars' might not be zero-terminated.

Naive Test Unit

```
unsigned char                       uChars[] = { 0x41, 0x42, 0x43, 0x44 };
const basic_string<unsigned char> kTextString3(uChars);
wstring                             resu
if (StringUtil::AsciiToUnicode(kTextSt
  return -1;
return 0;
```

(local variable) const std::basic_string<unsigned char> kTextString3

Search Online

C6054: String 'uChars' might not be zero-terminated.

It's worth paying attention to your squiggles !

VS analyzer does a pretty good job keeping you safe.

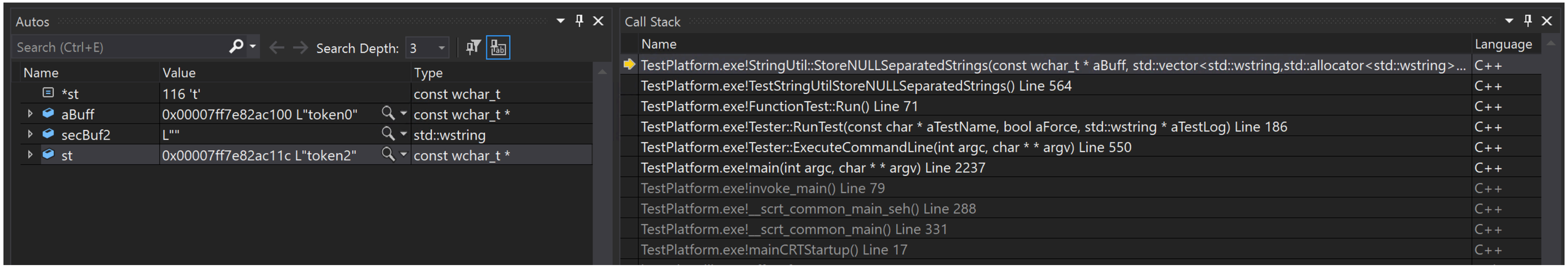
```
AddressSanitizer: global-buffer-overflow on address 0x00c158ca at pc 0x00838b91 bp 0x016fef98 sp
0x016fef8c
READ of size 2 at 0x00c158ca thread T0

    #0 0x838b90 in StringUtil::StoreNULLSeparatedStrings C:\JobAI\platform\util\strings\StringProcessing.cpp:430
    #1 0x67edfb in TestStringUtilStoreNULLSeparatedStrings C:\JobAI\testunits\strings\StringProcessingTests.cpp:563
    #2 0x7e8035 in FunctionTest::Run C:\JobAI\testunits\Tester.cpp:71
    #3 0x7e8901 in Tester::RunTest C:\JobAI\testunits\Tester.cpp:186
    #4 0x7e6d2b in Tester::ExecuteCommandLine C:\JobAI\testunits\Tester.cpp:558
    #5 0x7d9821 in main C:\JobAI\testunits\comps\TestComponents.cpp:2236
    #6 0x9d92f2 in invoke_main crt\vcstartup\src\startup\exe_common.inl:78
    #7 0x9d91f6 in __scrt_common_main_seh crt\vcstartup\src\startup\exe_common.inl:288
    #8 0x9d909c in __scrt_common_main crt\vcstartup\src\startup\exe_common.inl:330
    #9 0x9d9357 in mainCRTStartup crt\vcstartup\src\startup\exe_main.cpp:16

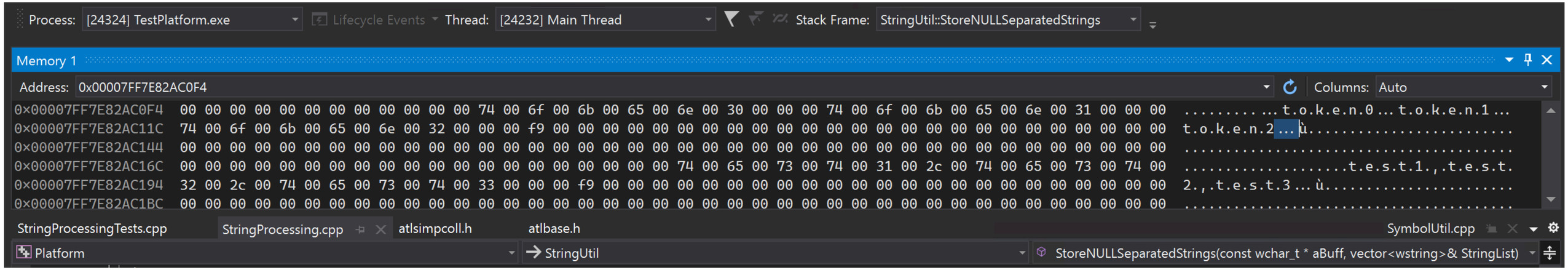
0x00c158ca is located 0 bytes to the right of global variable '<C++ string literal>' defined in
'StringProcessingTests.cpp:561:9' (0xc158a0) of size 42

SUMMARY:
AddressSanitizer: global-buffer-overflow StringProcessing.cpp:430 in StringUtil::StoreNULLSeparatedStrings
```

Use the full power of your Debugger



Use the full power of your Debugger



Excessive Test Unit

```
...

buff = L"token0\0token1\0token2\0";

list.clear();
StringUtil::StoreNULLSeparatedStrings(buff, list);

if (list.size() != 3)
  return -1;
if (list[2] != L"token2")
  return -1;

...
```

Excessive Test Unit

```
...

buff = L"token0\0token1\0token2\0";

list.clear();
StringUtil::StoreNULLSeparatedStrings(buff, list);

if (list.size() != 3)
  return -1;
if (list[2] != L"token2")
  return -1;

...
```

Excessive Test Unit

```
/**
 * Creates a vector with strings that are separated by \0
 * aBuff - buffer containing NULL separated strings
 * aLen - the length of buffer
 * aSection - vector that contains the strings from aBuff
 */
void StoreNULLSeparatedStrings(const wchar_t * aBuff, DWORD aLen,
                               vector<wstring> & aStringList);

/**
 * Creates a vector with strings that are separated by \0 and end with \0\0
 * aBuff - buffer containing NULL separated strings
 * aSection - vector that contains the strings from aBuff
 */
void StoreNULLSeparatedStrings(const wchar_t * aBuff, vector<wstring> & aStringList);
```

Excessive Test Unit

```
/**
 * Creates a vector with strings that are separated by \0
 * aBuff - buffer containing NULL separated strings
 * aLen - the length of buffer
 * aSection - vector that contains the strings from aBuff
 */
void StoreNULLSeparatedStrings(const wchar_t * aBuff, DW
                               vector<wstring> & aString

/**
 * Creates a vector with strings that are separated by \0 and end with \0\0
 * aBuff - buffer containing NULL separated strings
 * aSection - vector that contains the strings from aBuff
 */
void StoreNULLSeparatedStrings(const wchar_t * aBuff, vector<wstring> & aStringList);
```

OUT OF CONTRACT CALL

Just enough to wet your appetite

Go explore on your own...

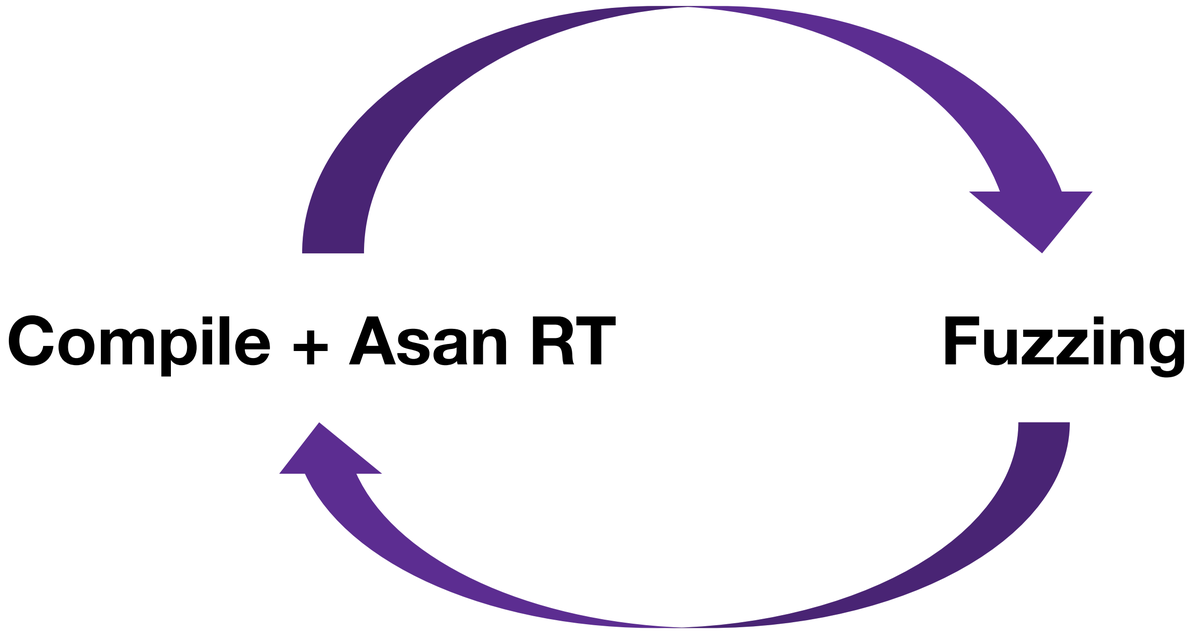
Part III

Warm Fuzzy Feelings

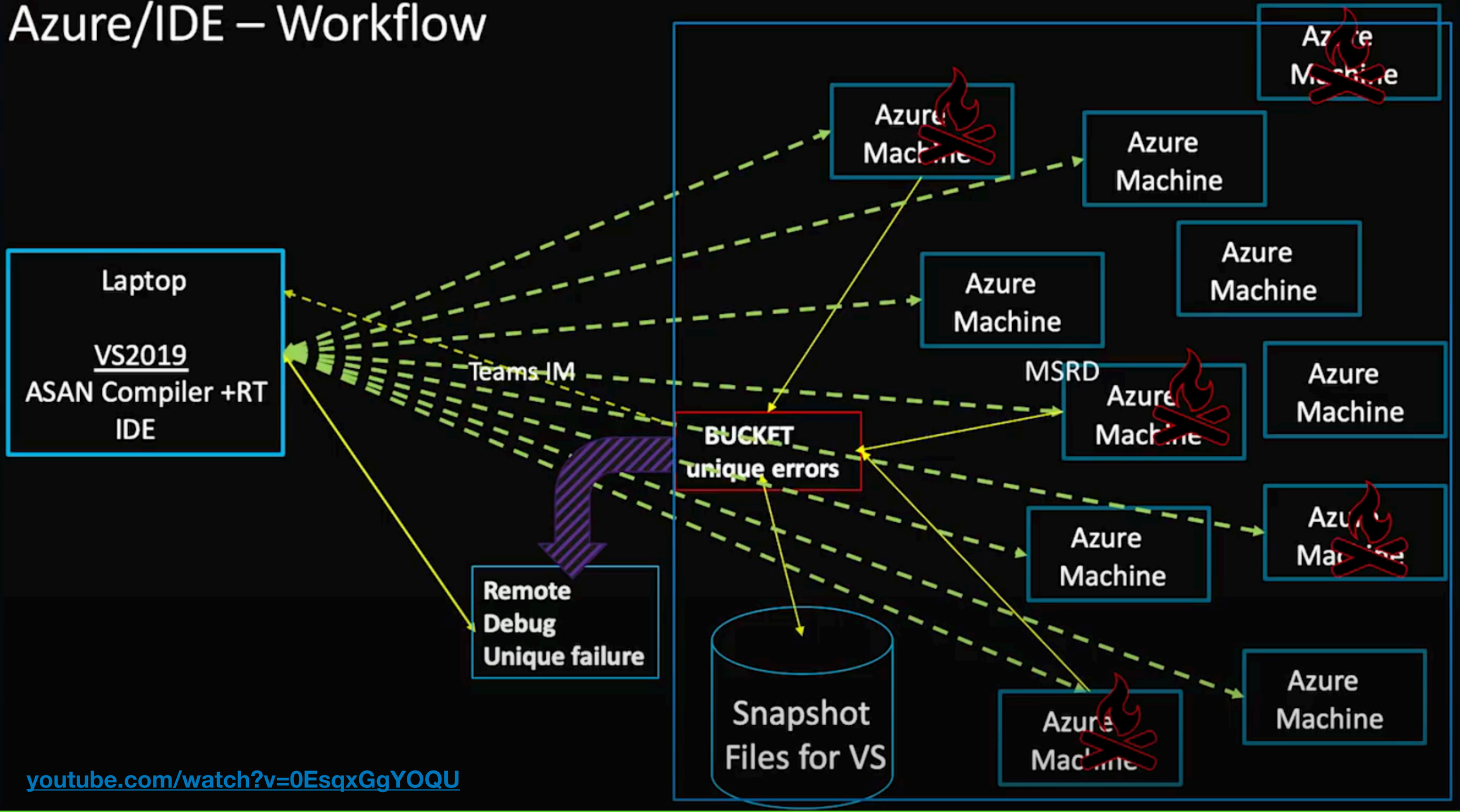
Sanitizers + Fuzzing

Automatically generate inputs to you program to crash it.

Workflow



Azure/IDE – Workflow



youtube.com/watch?v=0EsqxGgYOQU

Project OneFuzz

September 15, 2020

Microsoft announces new Project OneFuzz framework, an open source developer tool to find and fix bugs at scale

Justin Campbell Principal Security Software Engineering Lead, Microsoft Security

Mike Walker Senior Director, Special Projects Management, Microsoft Security

A self-hosted Fuzzing-As-A-Service platform

microsoft.com/security/blog/2020/09/15/microsoft-onefuzz-framework-open-source-developer-tool-fix-bugs/

A self-hosted Fuzzing-As-A-Service platform

github.com/microsoft/onefuzz

Project OneFuzz

CI/CD

🔥🔥🔥

New unique crashes create notifications:

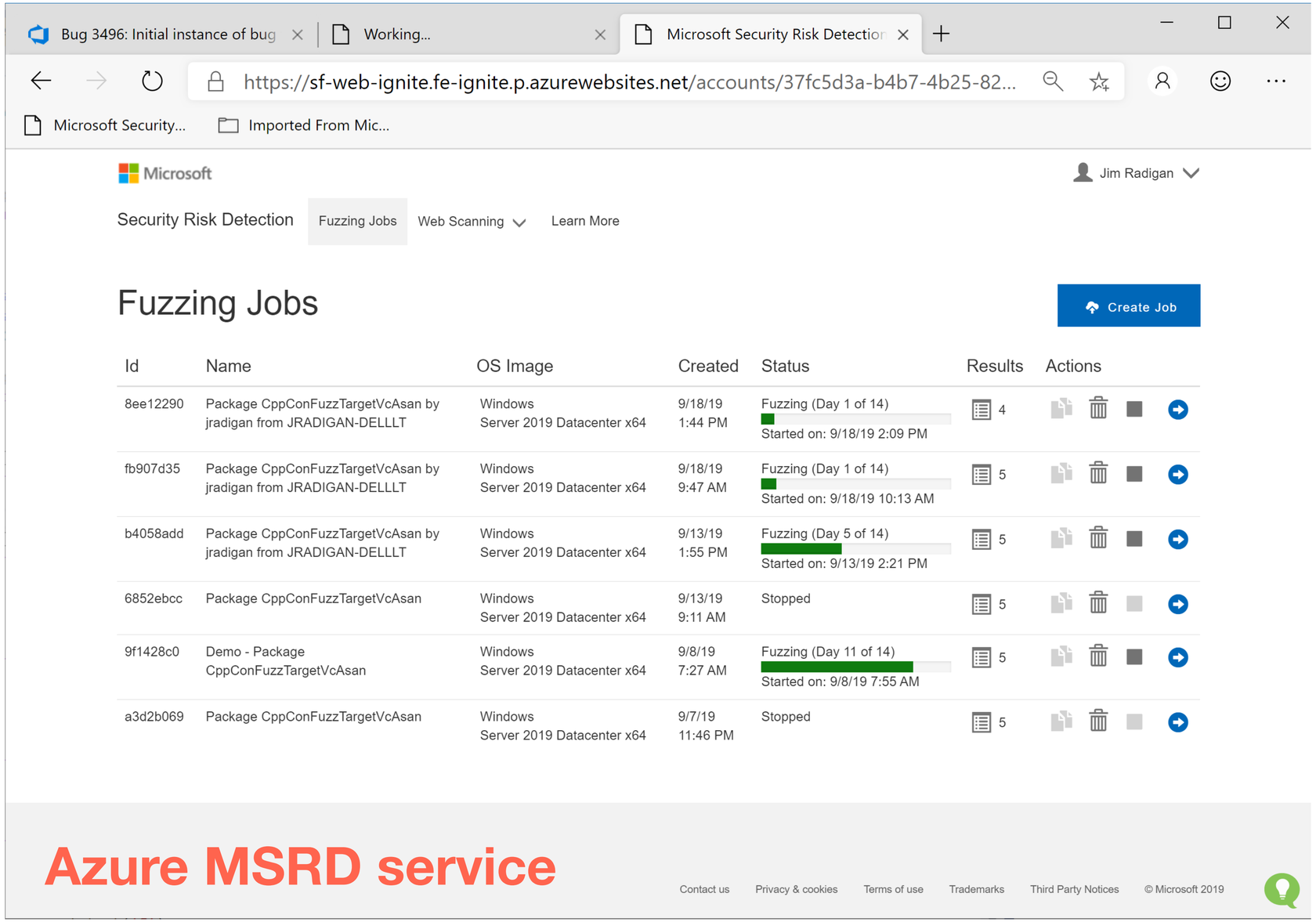
- **Teams**
- **ADO work items**

Azure DevOps Pipeline

GitHub Actions

github.com/microsoft/onefuzz-samples

{ ASan + Fuzzing } => Azure

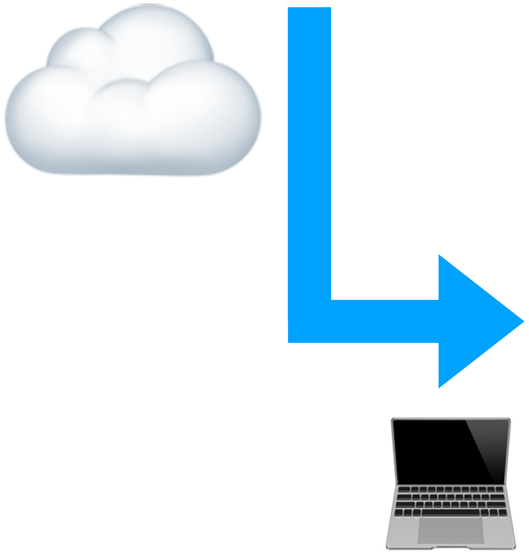


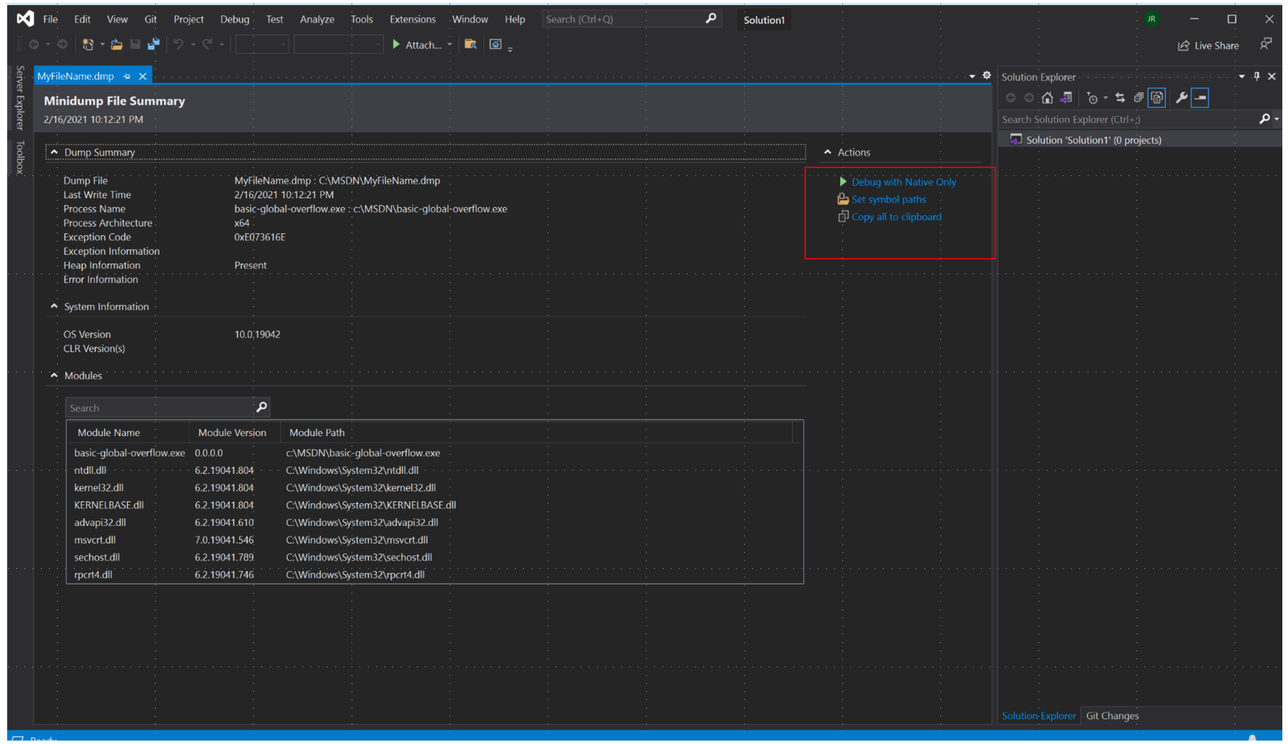
ASAN cloud / distributed testing

You can create the **dump** on test or production infrastructure
where the failure occurs, and debug it later on your developer PC

Crash dumps are created upon AddressSanitizer failures
by setting the following environment variable:

```
set ASAN_SAVE_DUMPS=MyFileName.dmp
```





docs.microsoft.com/en-us/cpp/sanitizers/asan-offline-crash-dumps

Q & A

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Memory Safety: Static vs Dynamic Analysis

Open4Tech

January 19, 2022

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