Meeting C++ 2020

ONLINE

September 24

2020: The Year of Sanitizers?

Victor Ciura

Principal Engineer

CAPHYON

@ciura_victor

Abstract

Clang-tidy is the go-to assistant for most 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.

Now that you're hooked on smart tools, you have to try dynamic/runtime analysis. After years of improvements and successes for Clang and GCC users, LLVM AddressSanitizer (ASan) is finally available on Windows, in the latest Visual Studio 2019 versions. Let's find out how this experience is for MSVC projects.

We'll 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 in Visual Studio, to pinpoint the failure.

Want to unleash the memory vulnerability beast? Put your test units on steroids, by spinning fuzzing jobs with ASan in Azure, leveraging the power of the Cloud from the comfort of your Visual Studio IDE.

Due to the nature of delivery medium &
streaming delays (up to 15-20 sec),
I prefer to take questions at the end*

Q & A ?

2020: The Year of Sanitizers?

Vignette in 3 parts

Static Analysis

Dynamic Analysis

Warm Fuzzy Feelings

Humans Depend on Tools

Programmers Depend on Tools

good code editor
(or IDE)

recent compiler(s)
[conformant/strict]

linter/formatter

perf profiler

powerful (visual) debugger

test framework

automated refactoring tools

build system

static analyzer

package manager

CI/CD service

dynamic analyzer
(runtime)

code reviews platform

SCM client

+ fuzzing

Why Do I Care ?

17 year old code base under active development
3.5 million lines of C++ code
a few brave nerds…

or

"How we manage to **clang-tidy** our whole code base,
while maintaining our monthly release cycle"

youtube.com/watch?v=Wl-9ozmxXbo

(CppCon 2017)

Who Am I ?

Advanced Installer

Clang Power Tools

@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

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

VS 16.7

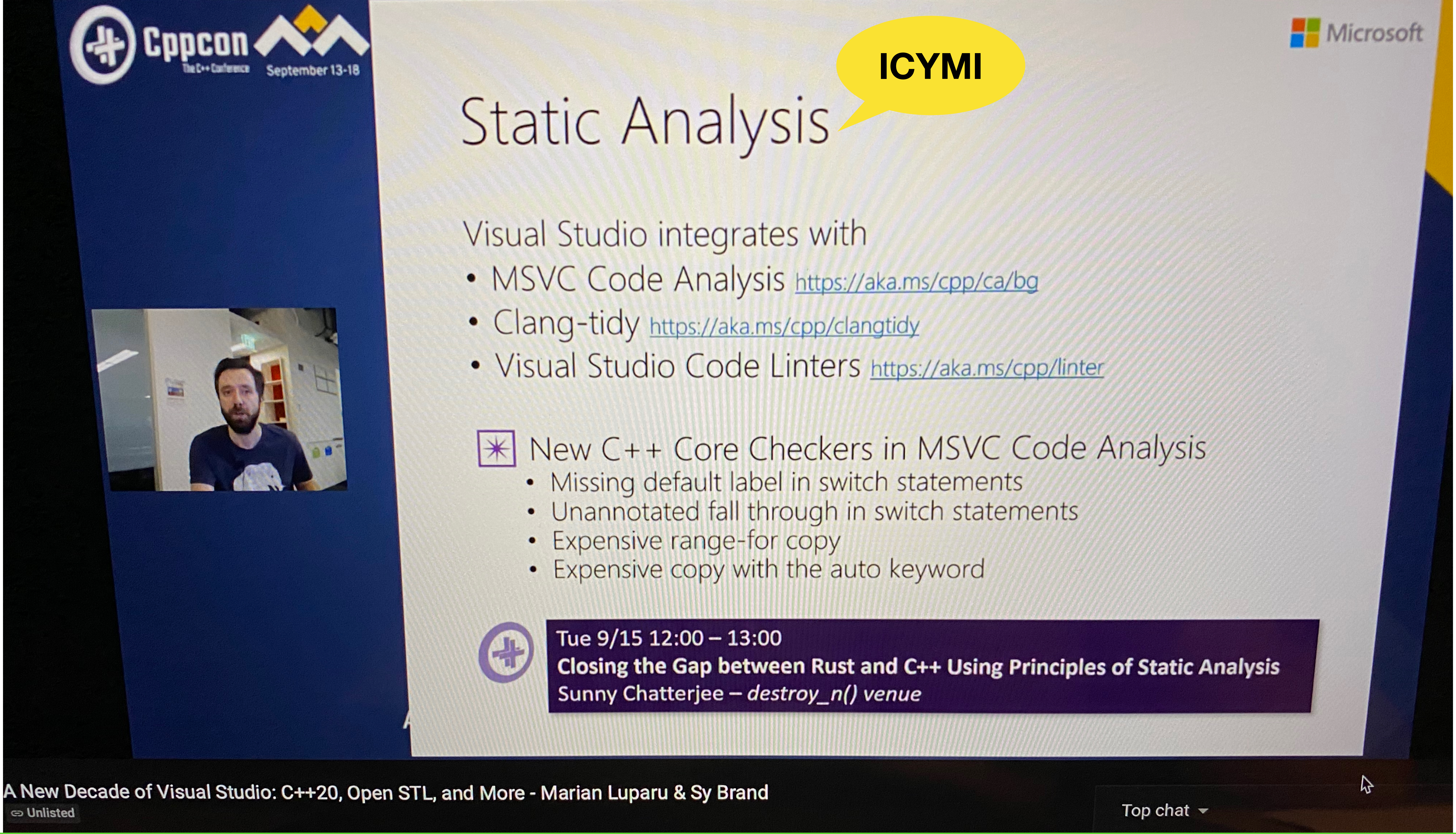
Standard C/C++ rule sets

Visual Studio includes these standard sets of rules for native code:

Rule Set	Description
C++ Core Check Arithmetic Rules	These rules enforce checks related to arithmetic operations from the C++ Core Guidelines.
C++ Core Check Bounds Rules	These rules enforce the Bounds profile of the C++ Core Guidelines.
C++ Core Check Class Rules	These rules enforce checks related to classes from the C++ Core Guidelines.
C++ Core Check Concurrency Rules	These rules enforce checks related to concurrency from the C++ Core Guidelines.
C++ Core Check Const Rules	These rules enforce const-related checks from the C++ Core Guidelines.
C++ Core Check Declaration Rules	These rules enforce checks related to declarations from the C++ Core Guidelines.
C++ Core Check Enum Rules	These rules enforce enum-related checks from the C++ Core Guidelines.
C++ Core Check Experimental Rules	These rules collect some experimental checks. Eventually, we expect these checks to be moved to other rulesets or removed completely.
C++ Core Check Function Rules	These rules enforce checks related to functions from the C++ Core Guidelines.
C++ Core Check GSL Rules	These rules enforce checks related to the Guidelines Support Library from the C++ Core Guidelines.

● ● ●

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


Cppcon
The C++ Conference
September 13-18
Microsoft
ICYMI
Static Analysis
Visual Studio integrates with
• MSVC Code Analysis https://aka.ms/cpp/ca/bg
• Clang-tidy https://aka.ms/cpp/clangtidy
• Visual Studio Code Linters https://aka.ms/cpp/linter
New C++ Core Checkers in MSVC Code Analysis
• Missing default label in switch statements
• Unannotated fall through in switch statements
• Expensive range-for copy
• Expensive copy with the auto keyword
Tue 9/15 12:00 – 13:00
Closing the Gap between Rust and C++ Using Principles of Static Analysis
Sunny Chatterjee – destroy_n() venue
A New Decade of Visual Studio: C++20, Open STL, and More - Marian Luparu & Sy Brand
Unlisted
Top chat

`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-*

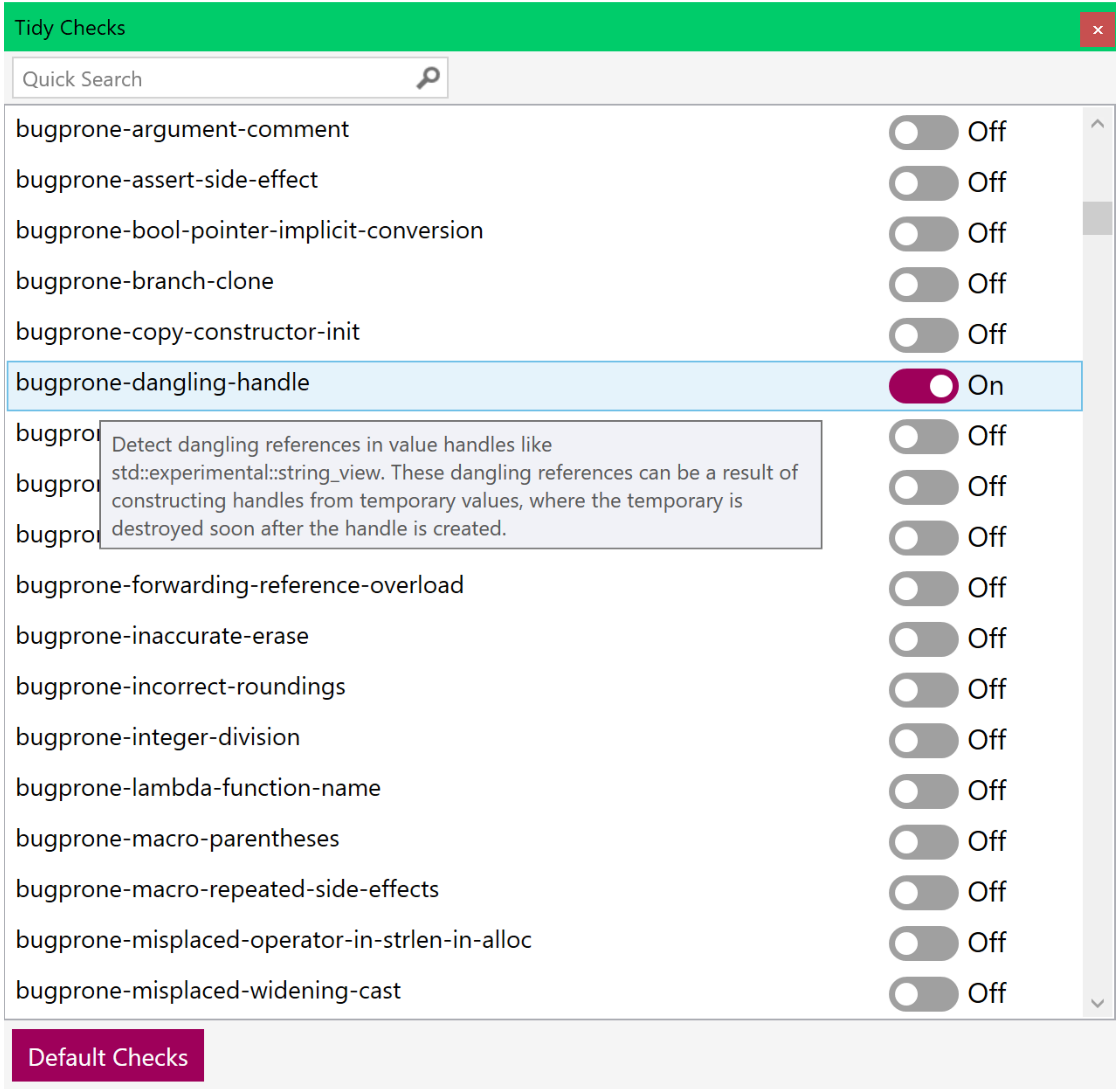
clang-tidy

- 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 profile v1.0

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 profile v1.0

Lifetime safety: Preventing common dangling

```
void example()
{
  std::string_view sv = std::string("dangling"); // A
  std::cout << sv;
}
```

clang -Wlifetime

Experimental

CppCoreGuidelines

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

Lifetime profile v1.0

Lifetime safety: Preventing common dangling

```
void example()
{
  std::string_view sv = std::string("dangling"); // A
  std::cout << sv;              // ERROR (lifetime.3): ‘sv’ was invalidated when
}                               // temporary was destroyed (line A)
```

`clang -Wlifetime` **Experimental**

CppCoreGuidelines

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

Lifetime safety: Preventing common dangling

[-Wdangling-gsl] **diagnosed by default in 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

[-Wdangling-gsl] **diagnosed by default in Clang 10**

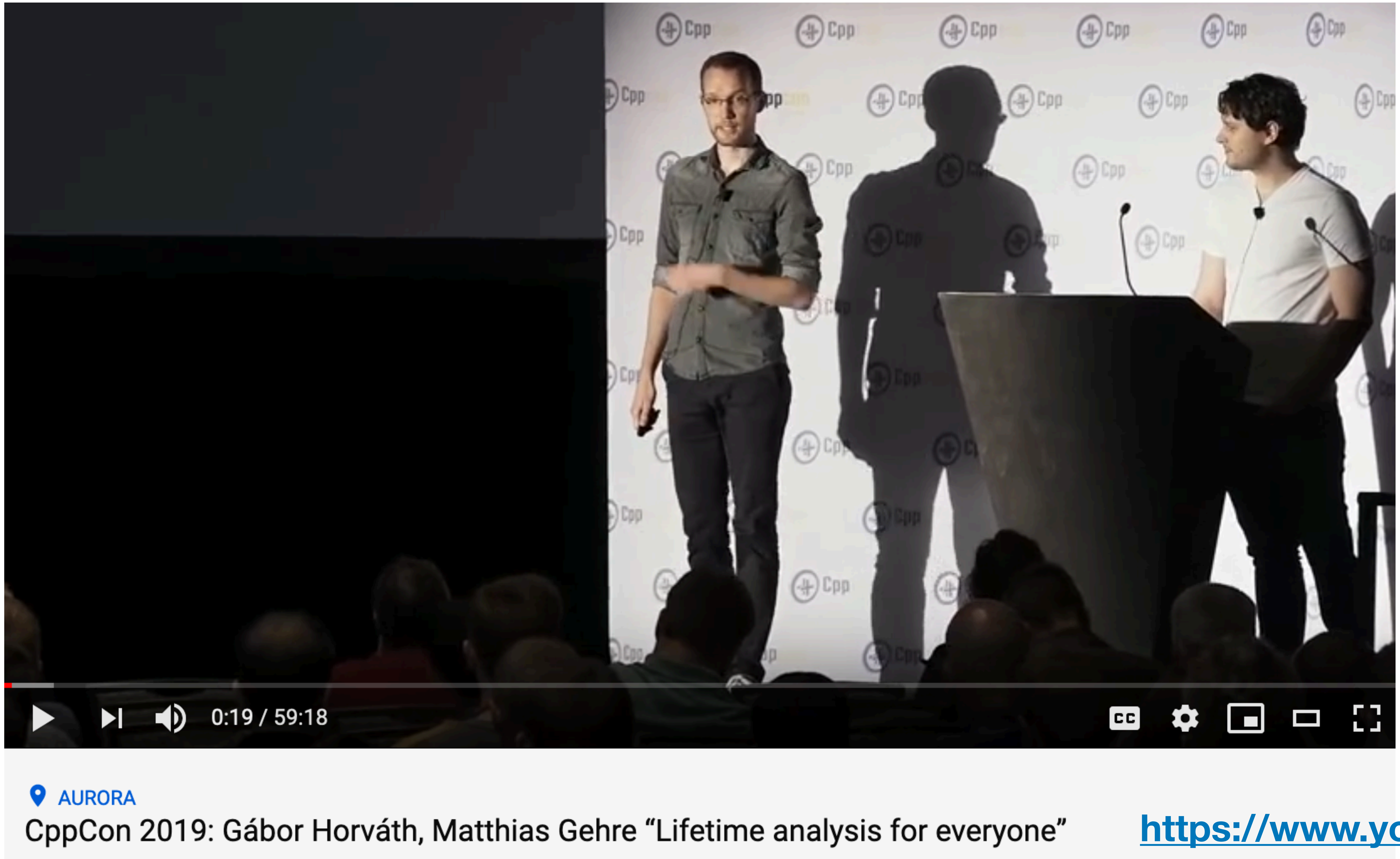
warning: initializing pointer member to point to a temporary object whose lifetime is shorter than the lifetime of the constructed object

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

Lifetime profile

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



https://www.youtube.com/watch?v=d67kfSnhbpA

clang-tidy

Checks are organized in **modules**, which can be linked into clang-tidy with minimal or no code changes in clang-tidy

clang-tidy

Checks are organized in **modules**, which can be linked into clang-tidy
with minimal or no code changes in clang-tidy

Checks can plug into the analysis on the **preprocessor** level using **PPCallbacks**
or on the AST level using **AST Matchers**

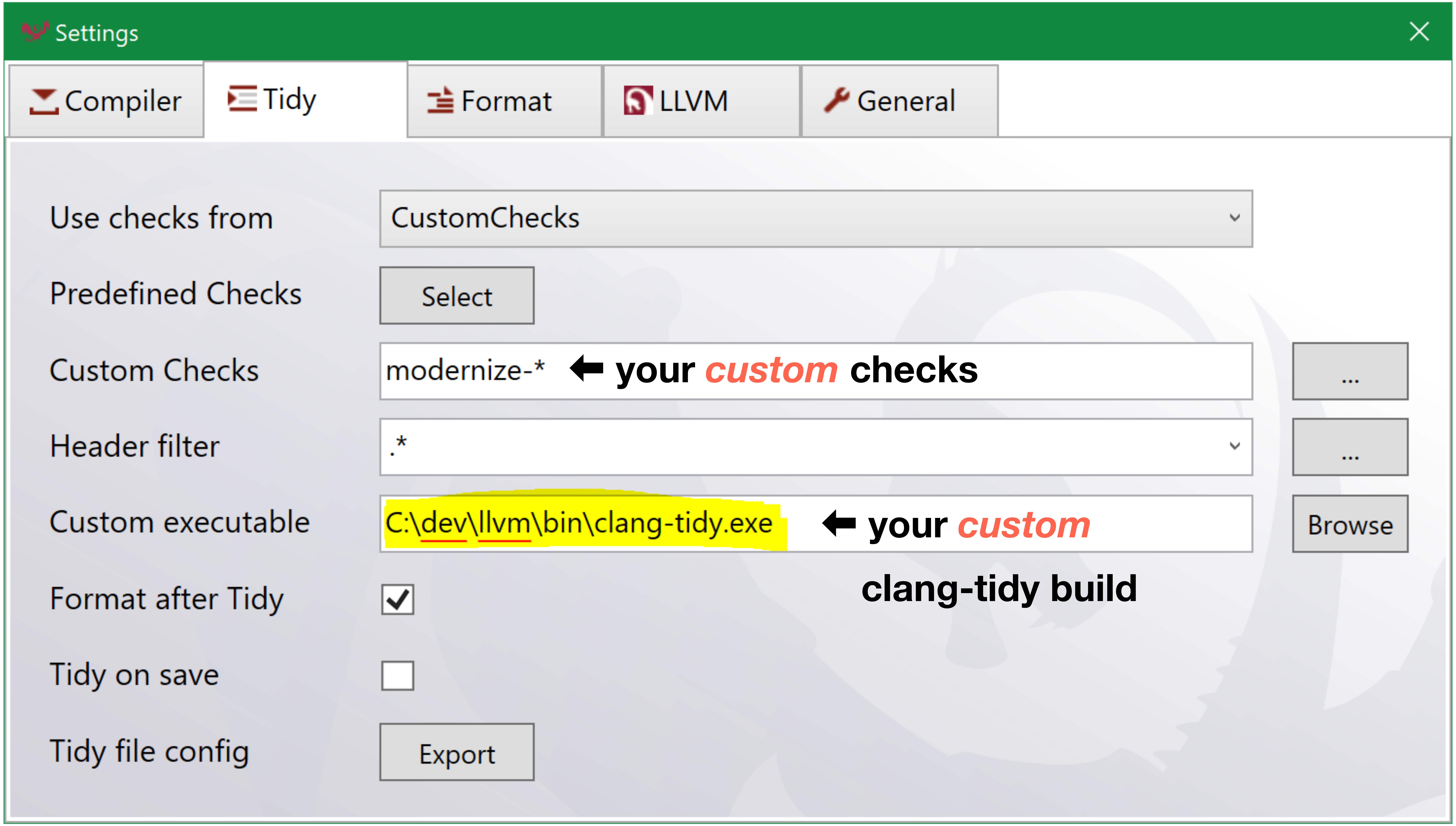
`clang-tidy`

Checks are organized in **modules**, which can be linked into clang-tidy with minimal or no code changes in clang-tidy

Checks can plug into the analysis on the **preprocessor** level using **PPCallbacks** or on the AST level using **AST Matchers**

Checks can **report** issues in a similar way to how Clang diagnostics work. A **fix-it** hint can be attached to a diagnostic message

Custom clang-tidy checks



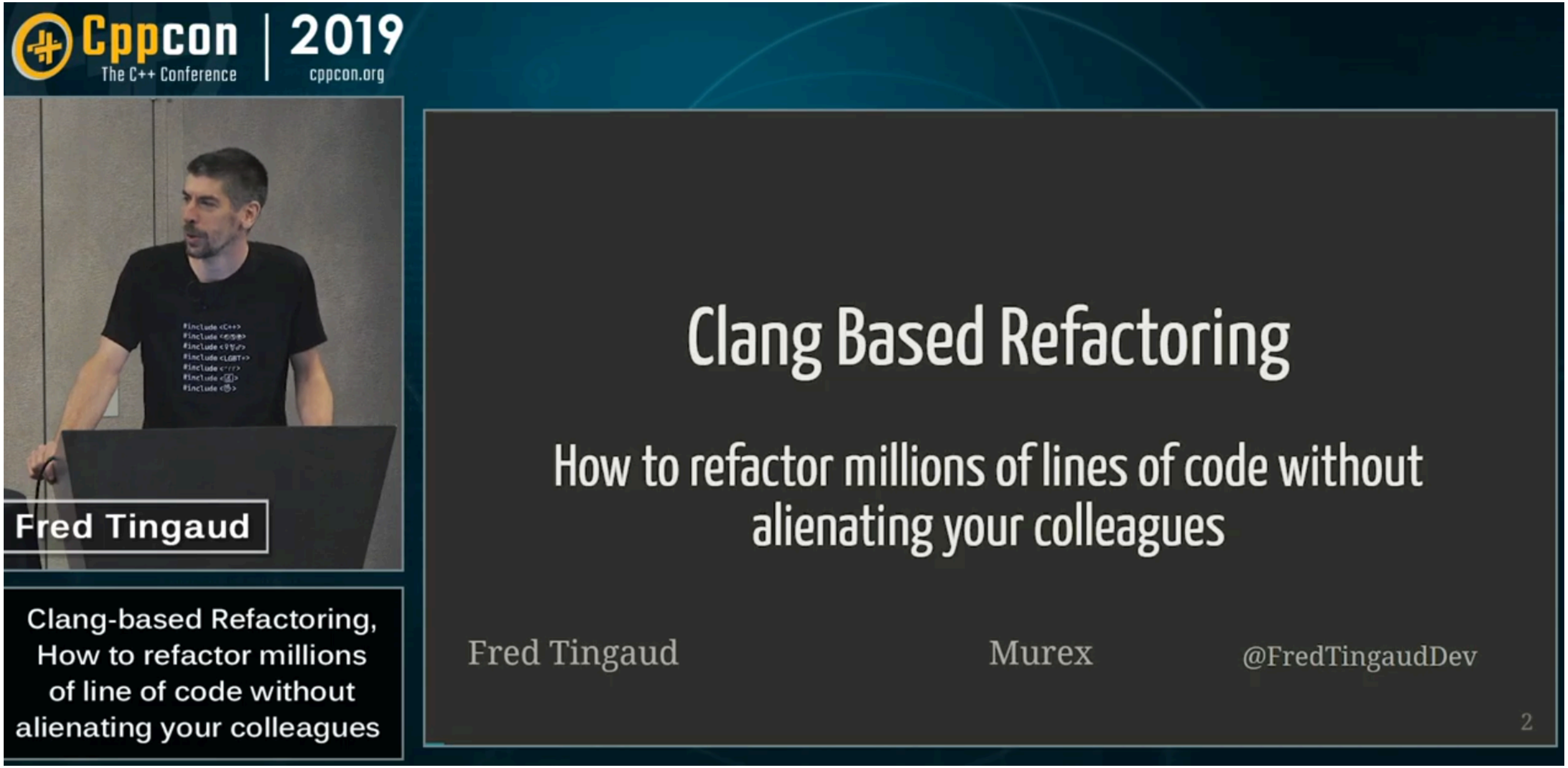
Write *custom* checks for your needs
(project specific)

Run them regularly !

Explore Further

https://steveire.wordpress.com/2019/01/02/refactor-with-clang-tooling-at-codedive-2018/

Explore Further



https://www.youtube.com/watch?v=JPnN2c2odNY

www.youtube.com/watch?v=Iz4C29yul2U

Explore Further

A new series of blog articles on **Visual C++ Team blog** by **Stephen Kelly**

Exploring Clang Tooling, Part 0: Building Your Code with Clang

https://blogs.msdn.microsoft.com/vcblog/2018/09/18/exploring-clang-tooling-part-0-building-your-code-with-clang/

Exploring Clang Tooling, Part 1: Extending Clang-Tidy

https://blogs.msdn.microsoft.com/vcblog/2018/10/19/exploring-clang-tooling-part-1-extending-clang-tidy/

Exploring Clang Tooling, Part 2: Examining the Clang AST with clang-query

https://blogs.msdn.microsoft.com/vcblog/2018/10/23/exploring-clang-tooling-part-2-examining-the-clang-ast-with-clang-query/

Explore Further

A new series of blog articles on **Visual C++ Team blog** by **Stephen Kelly**

Exploring Clang Tooling, Part 3: Rewriting Code with clang-tidy

https://blogs.msdn.microsoft.com/vcblog/2018/11/06/exploring-clang-tooling-part-3-rewriting-code-with-clang-tidy/

Exploring Clang Tooling: Using Build Tools with clang-tidy

https://blogs.msdn.microsoft.com/vcblog/2018/11/27/exploring-clang-tooling-using-build-tools-with-clang-tidy/

Explore Further

More blog articles by **Stephen Kelly**

Future Developments in clang-query

https://steveire.wordpress.com/2018/11/11/future-developments-in-clang-query/

Composing AST Matchers in clang-tidy

https://steveire.wordpress.com/2018/11/20/composing-ast-matchers-in-clang-tidy/

Visual Studio 2019
v16.2

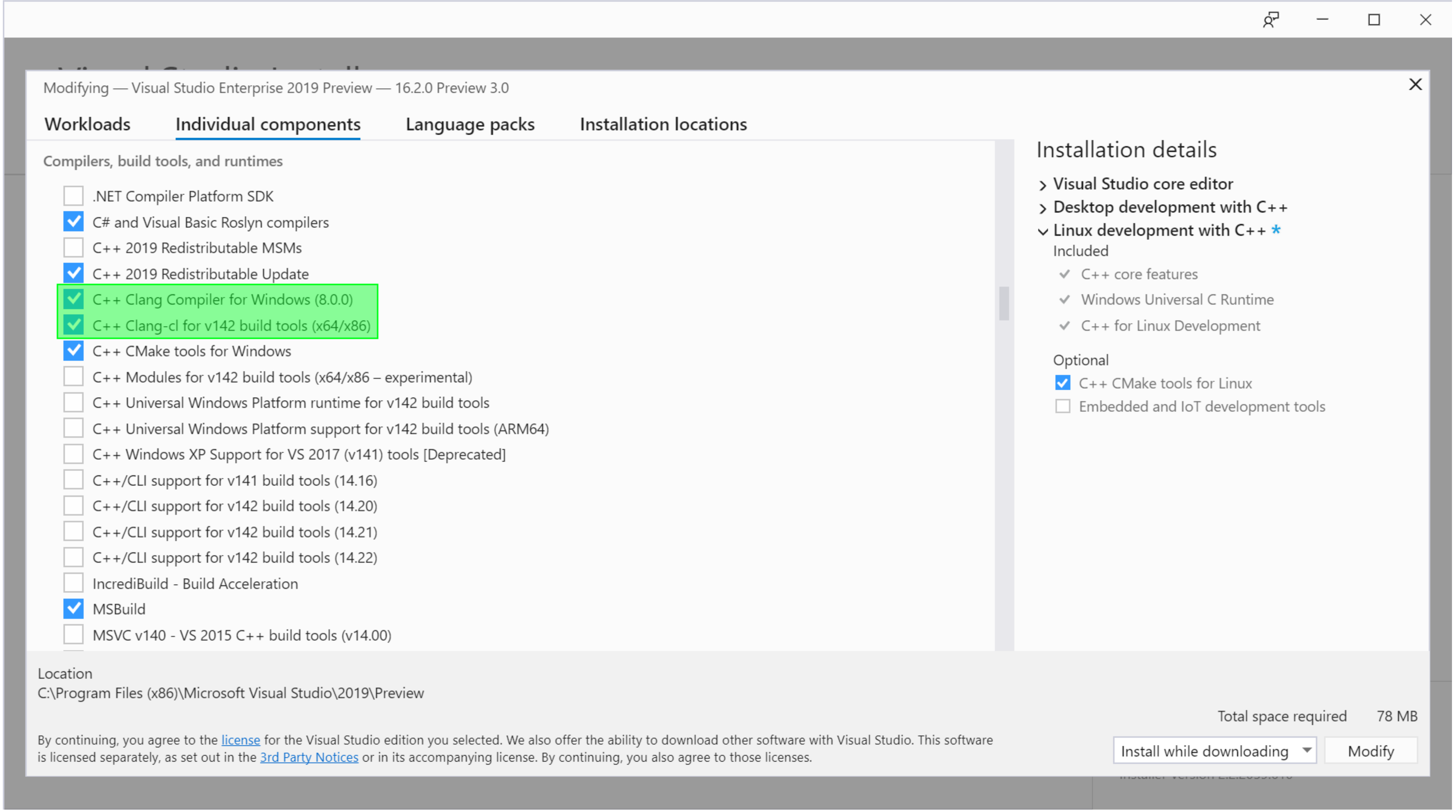
`Clang/LLVM` support for `MSBuild` & `CMake` Projects

Ships with `Clang` (as optional component)

`clang-cl.exe`

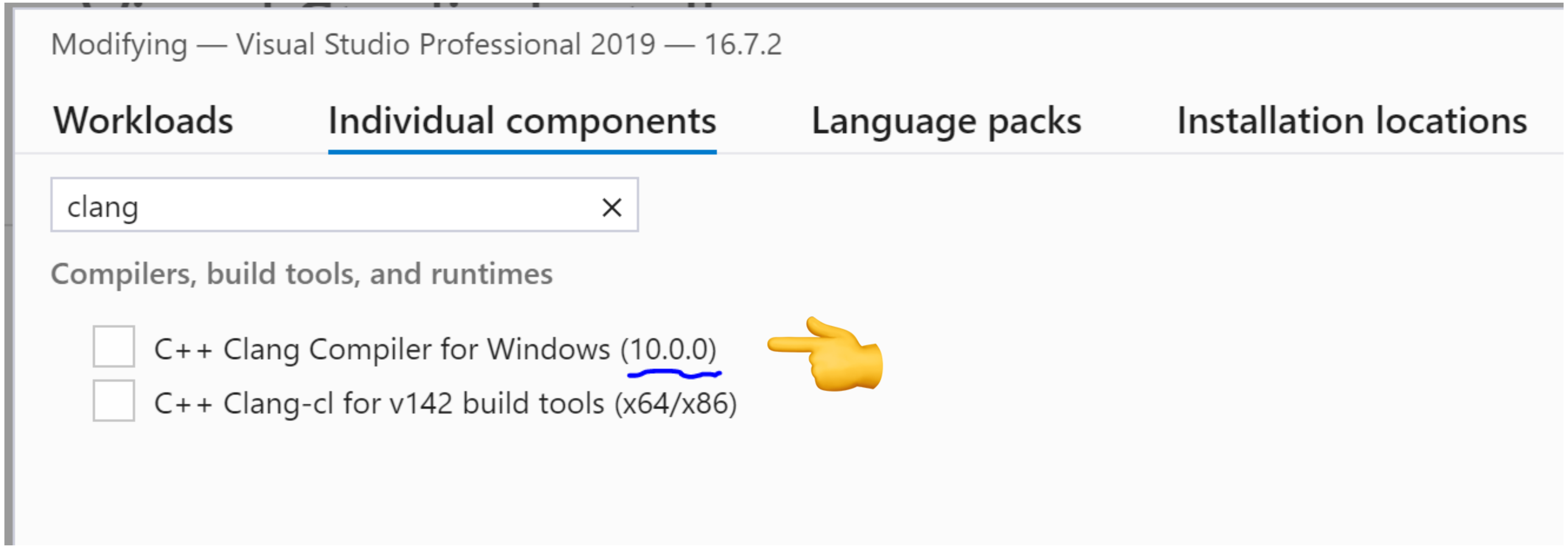
https://devblogs.microsoft.com/cppblog/clang-llvm-support-for-msbuild-projects/

Visual Studio 2019
v16.2

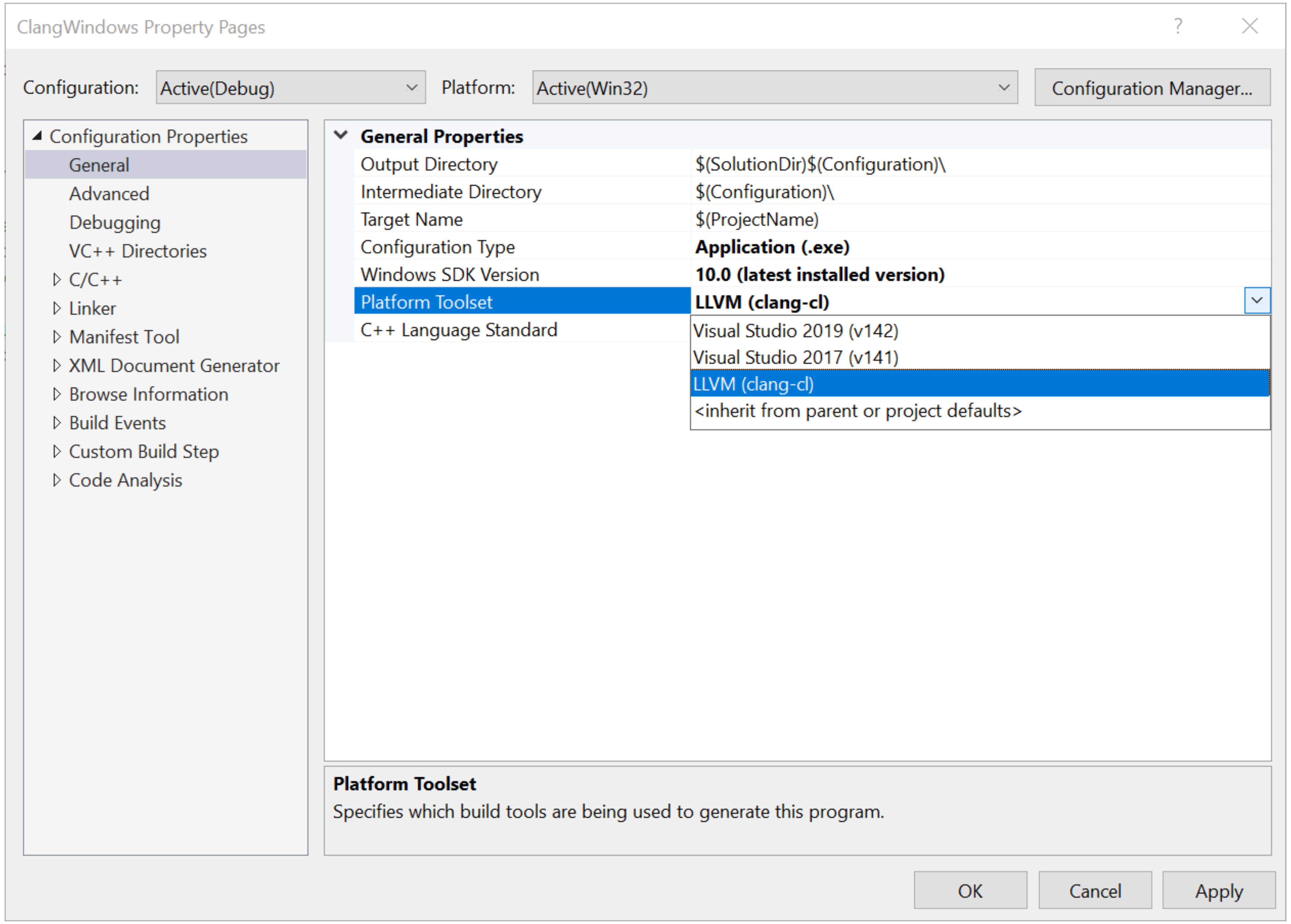


Visual Studio 2019

v16.7



Visual Studio 2019
v16.2



`clang-cl.exe`

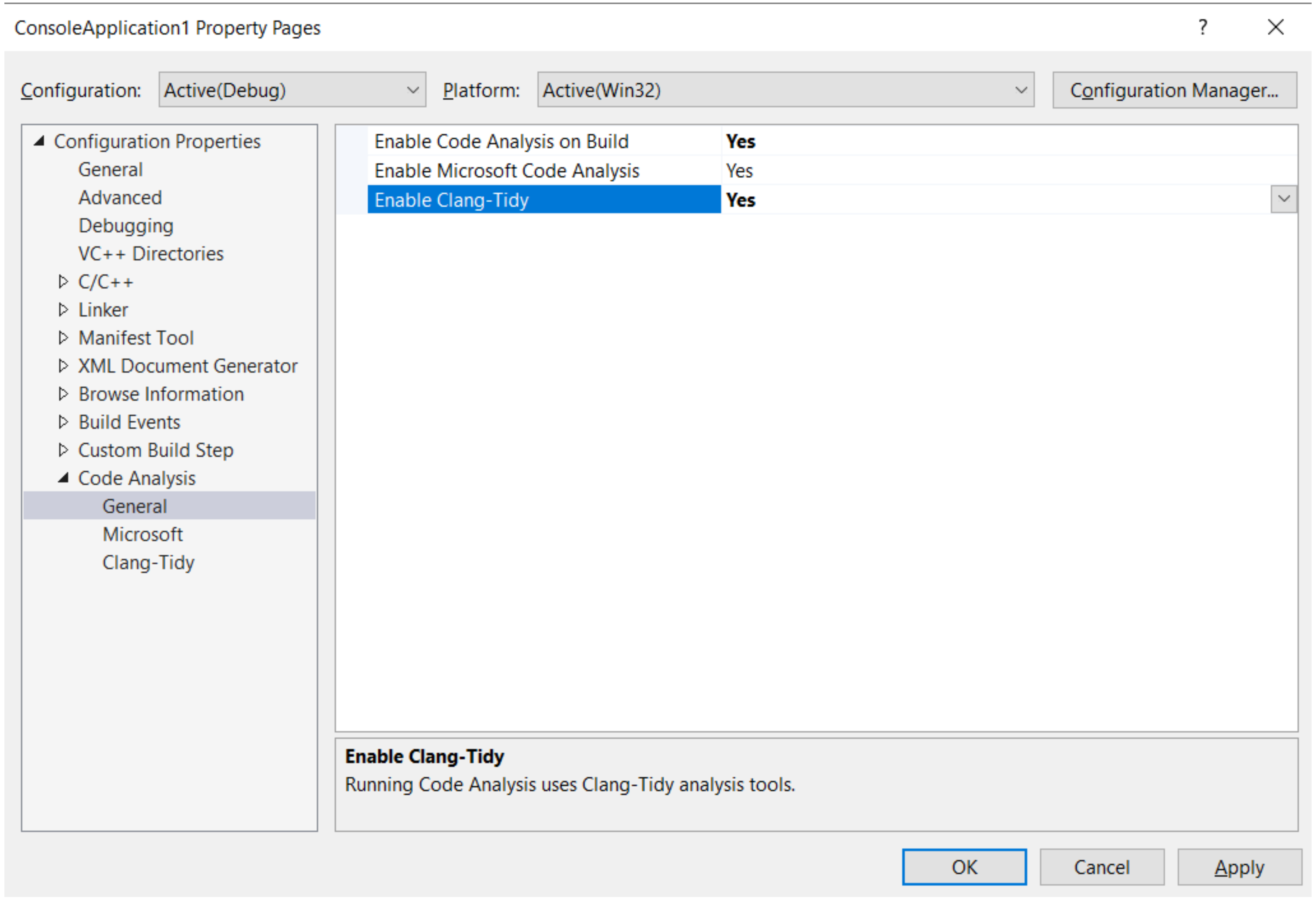
Visual Studio 2019
v16.4

`clang-tidy`

code analysis

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

Visual Studio 2019
v16.4



Visual Studio 2019
v16.4

`clang-tidy` **warnings**

Error List

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

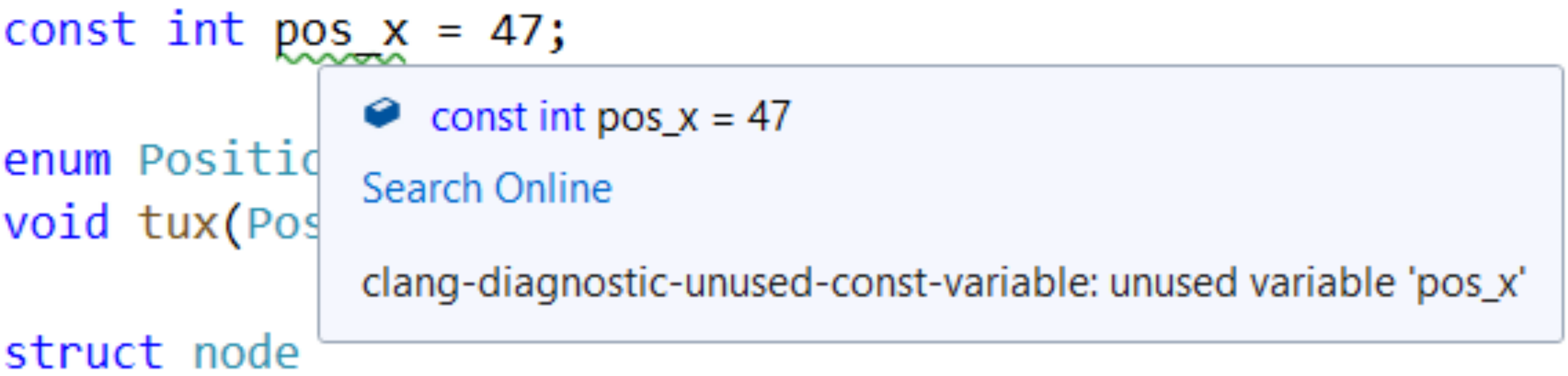
Code	Description	File	Line	Col	Category
readability-isolate-declaration	multiple declarations in a single statement reduces readability	CMAKEDEMO.CPP	23	2	readability
modernize-use-nullptr	use nullptr	CMAKEDEMO.CPP	31	7	modernize
cppcoreguidelines-macro-usage	macro 'TRUE' used to declare a constant; 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
v16.4

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



Code Analysis runs automatically in the background

NOT on
Visual Studio 2019 v16.4+
yet ?

No problem

Clang Power Tools = LLVM -> Visual Studio

Clang Power Tools

www.clangpowertools.com

LLVM

clang-tidy
clang++
clang-format
clang-check/query

Visual Studio

2015 / 2017 / 2019

Static vs Dynamic Analysis

Static Analysis

- offline (out of the normal compilation cycle) => can take longer to process source code
- is intimately linked to the used programming language
- can detect a lot of semantic issues
- can yield a lot of false positive results (sometimes you go on a wild goose chase)
- very poor at whole program analysis (follow connections in different TUs)
- almost helpless around virtual functions (difficult to de-virtualize calls)
- weak analysis ability around global pointers
- pointer aliasing makes it hard to prove things (alias analysis is hard problem)
- vicious cycle: type propagation <> alias analysis

Dynamic Analysis

- sometimes intrusive: you need to compile the program in a special mode
- runtime overhead (performance impact: depending on tool, from **2x** up to **10x**)
- extra-memory usage (for memory related tools/instrumentation), 2x or more
- sometimes difficult to map error reports into source code for Release/optimized builds (symbols info, line numbers, inlined functions)
- some tools require to recompile the whole program in instrumented mode
- must integrate runtime analysis with Test Units
- must ensure good code coverage for the runtime analysis (all possible scenarios)
- the biggest impact when combined with fuzzing

Dynamic Analysis

- sometimes intrusive: you need to compile the program in a special mode
- runtime overhead (performance impact: depending on tool, from **2x** up to **10x**)
- extra-memory usage (for memory related tools/instrumentation), 2x or more
- sometimes difficult to map error reports into source code for Release/optimized builds (symbols info, line numbers, inlined functions)
- some tools require to recompile the whole program in instrumented mode
- must integrate runtime analysis with Test Units
- must ensure good code coverage for the runtime analysis (all possible scenarios)
- the biggest impact when combined with fuzzing

0 false positives!

Part II

Dynamic Analysis

ICYMI

Control Flow Guard

`/guard:cf`

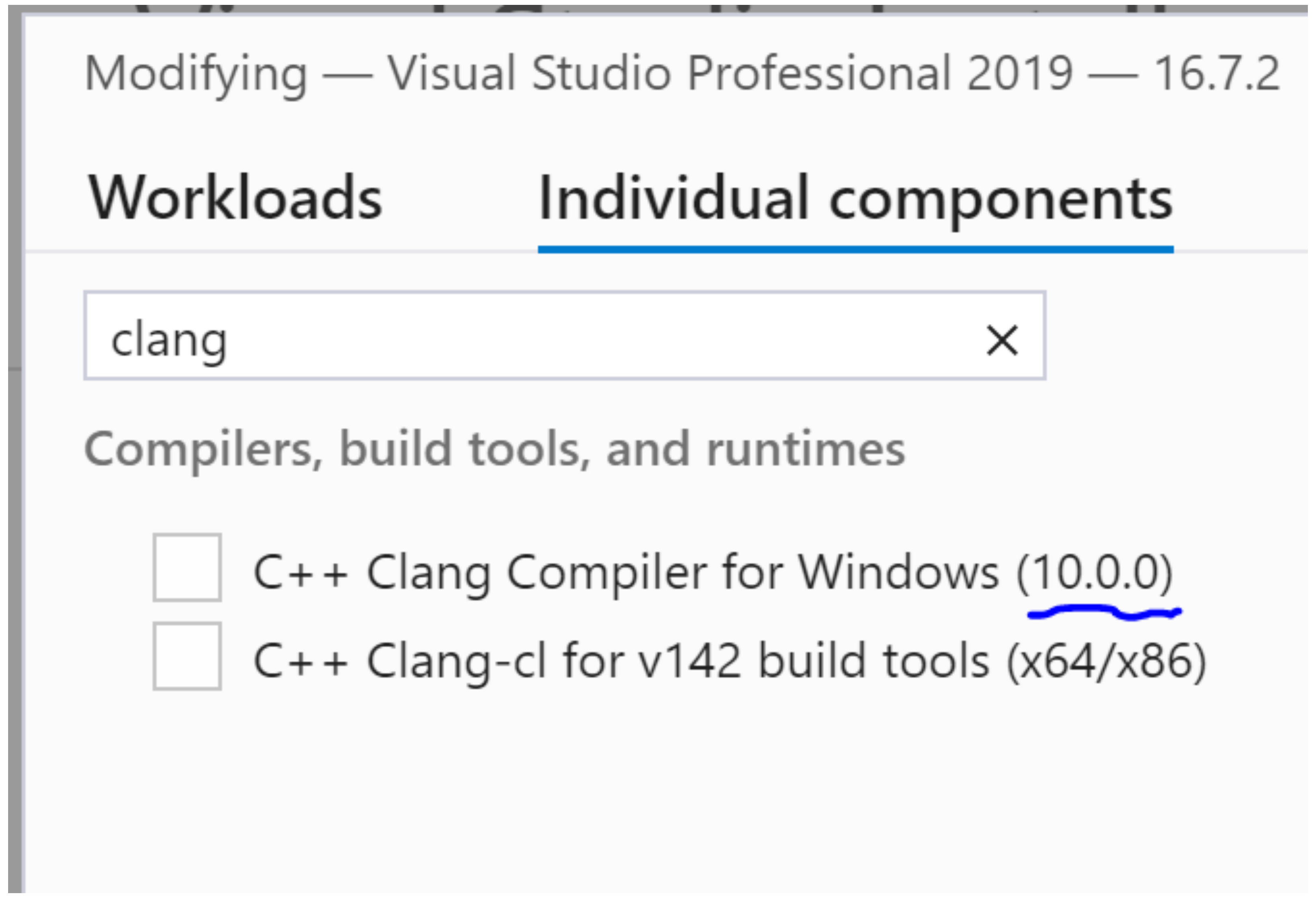
Enforce control flow integrity (Windows 8.1 & Windows 10)

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

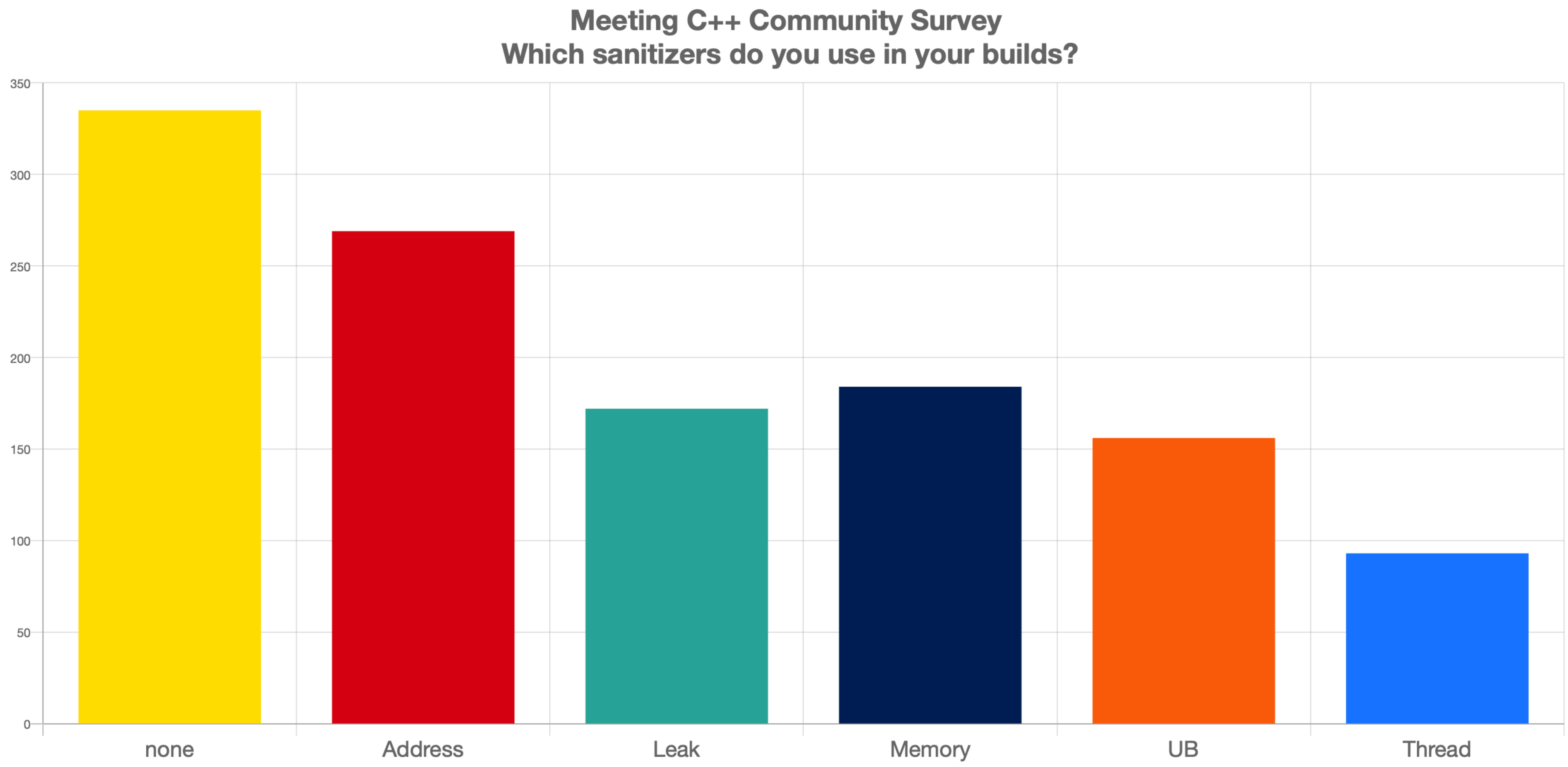
- `AddressSanitizer` - detects addressability issues
- `LeakSanitizer` - detects memory leaks
- `ThreadSanitizer` - detects data races and deadlocks
- `MemorySanitizer` - detects use of uninitialized memory
- `HWASAN` - hardware-assisted AddressSanitizer (consumes less memory)
- `UBSan` - detects Undefined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

github.com/google/sanitizers

Meeting C++ Community Survey

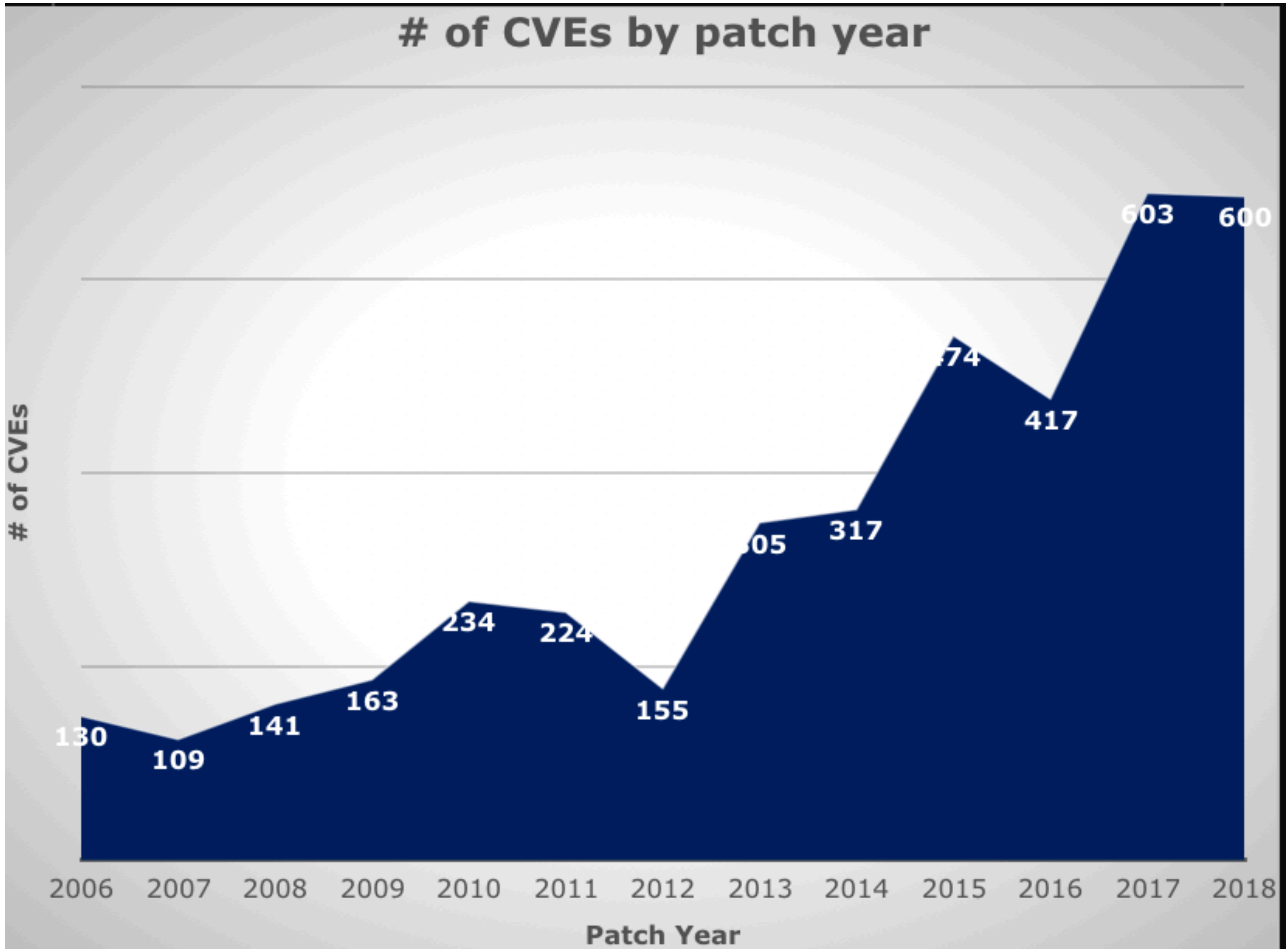
meetingcpp.com/mcpp/survey/?q=19

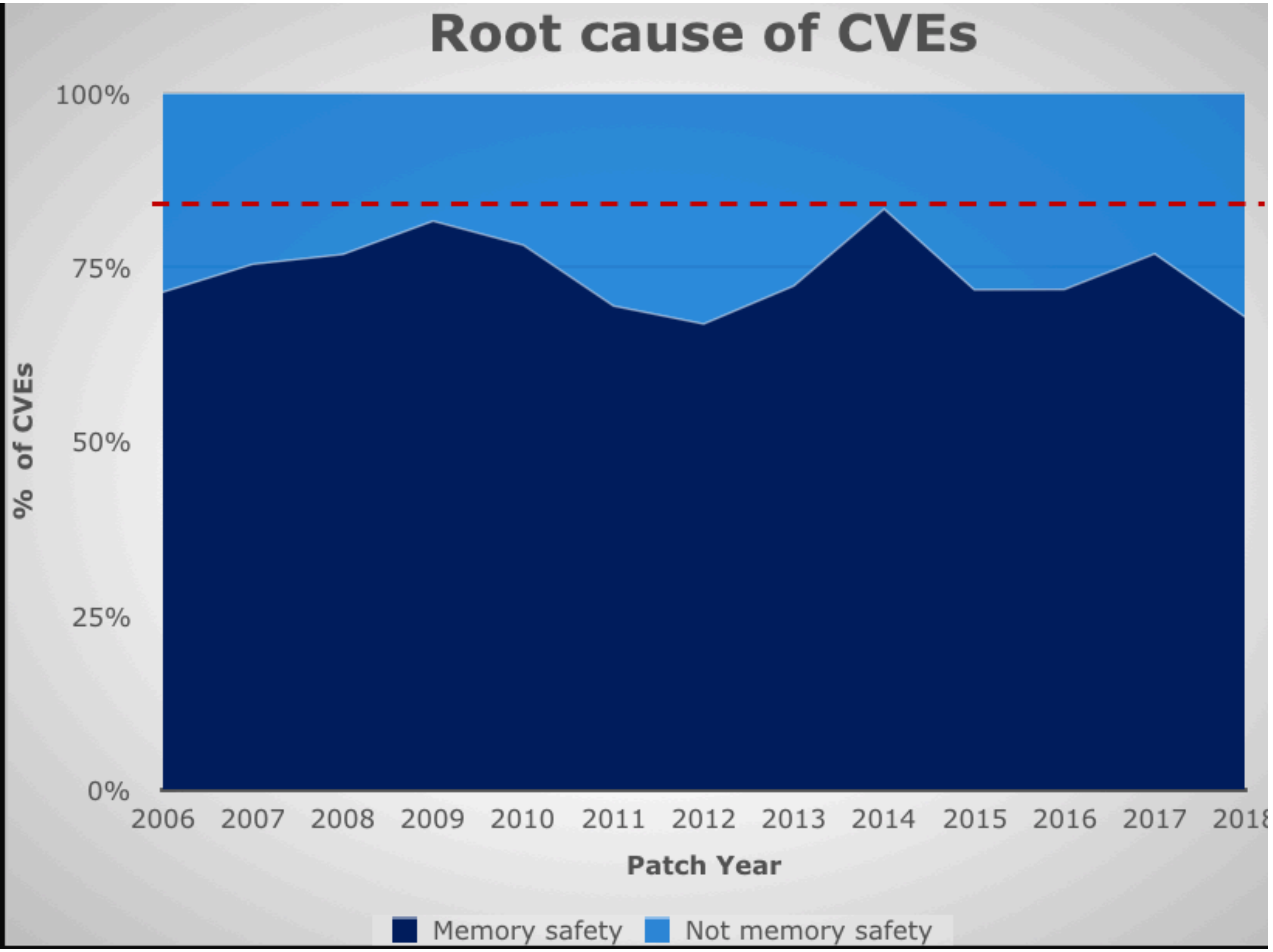
Next Question | Survey results



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** (late 2019)

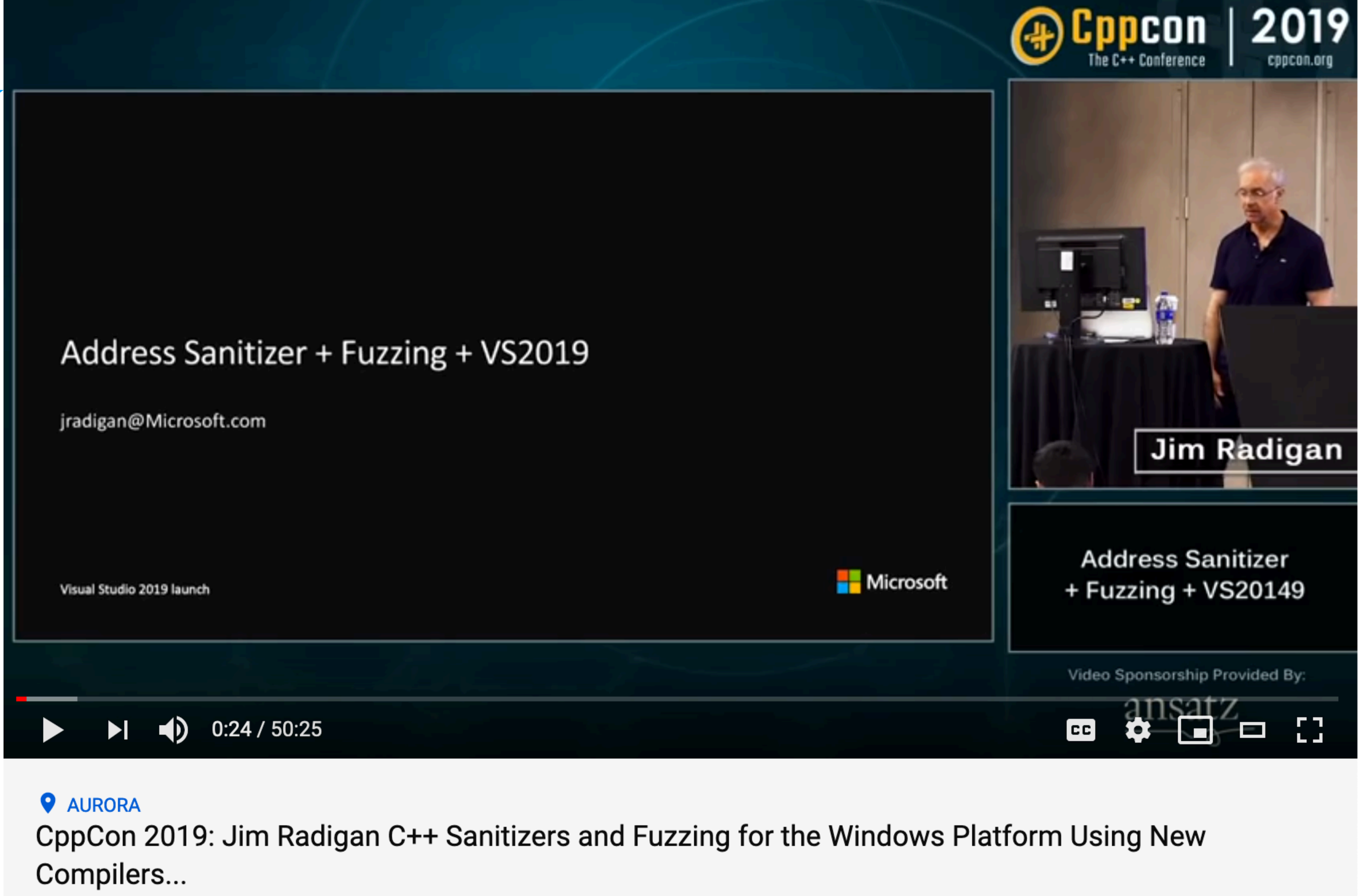
Visual Studio 2019
v16.4
October 2019

Address Sanitizer
(ASan)

🎉

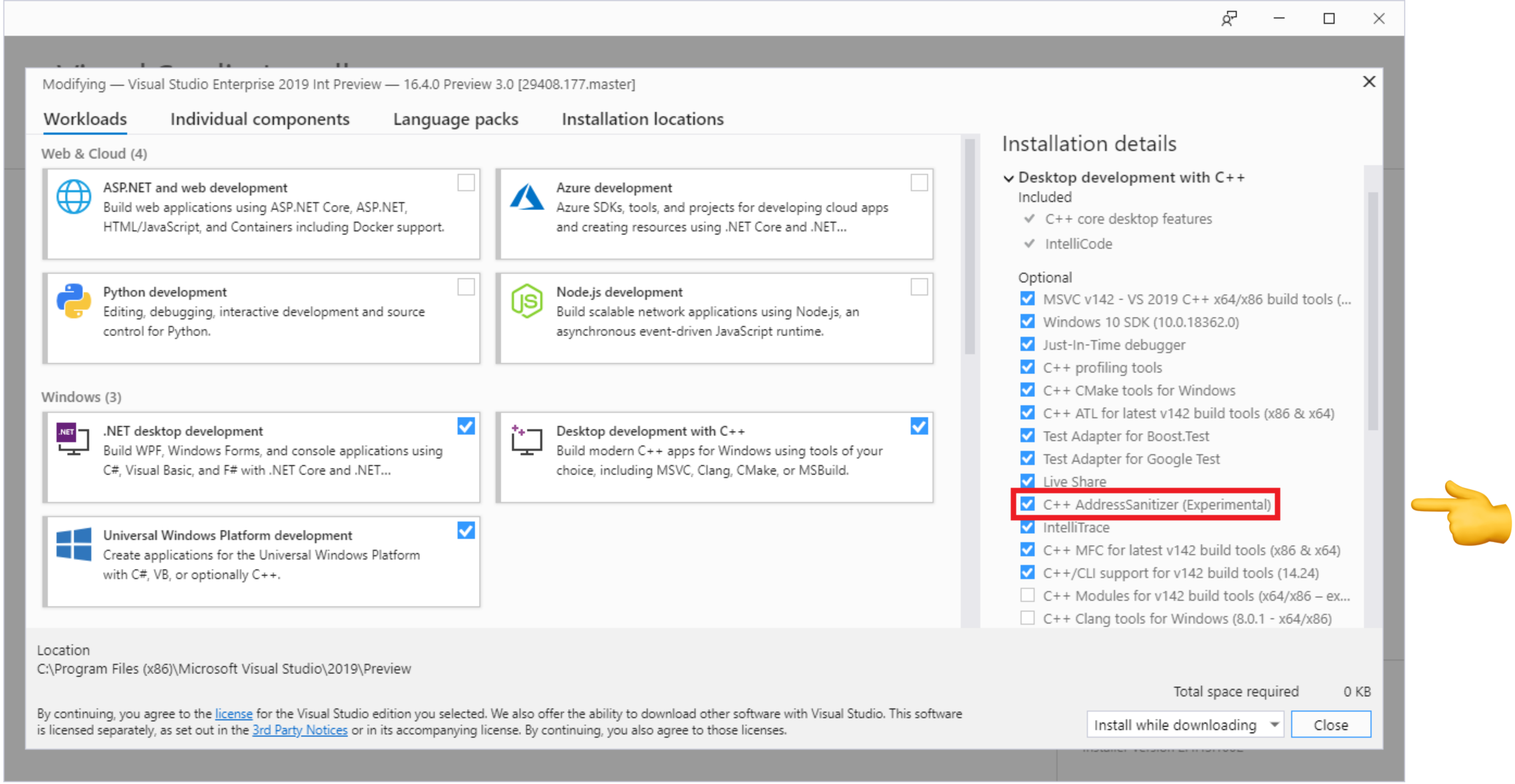
📖 devblogs.microsoft.com/cppblog/addresssanitizer-asan-for-windows-with-msvc/

sneak peek



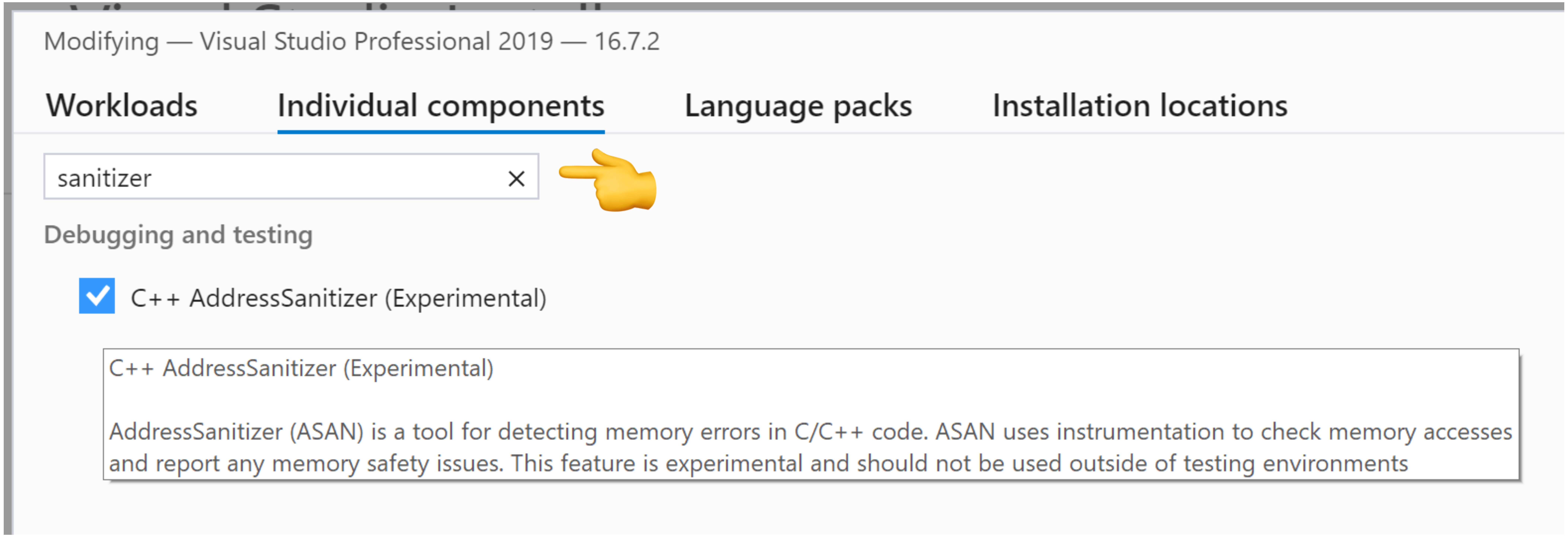
https://www.youtube.com/watch?v=0EsqxGgYOQU

Visual Studio 2019
v16.4



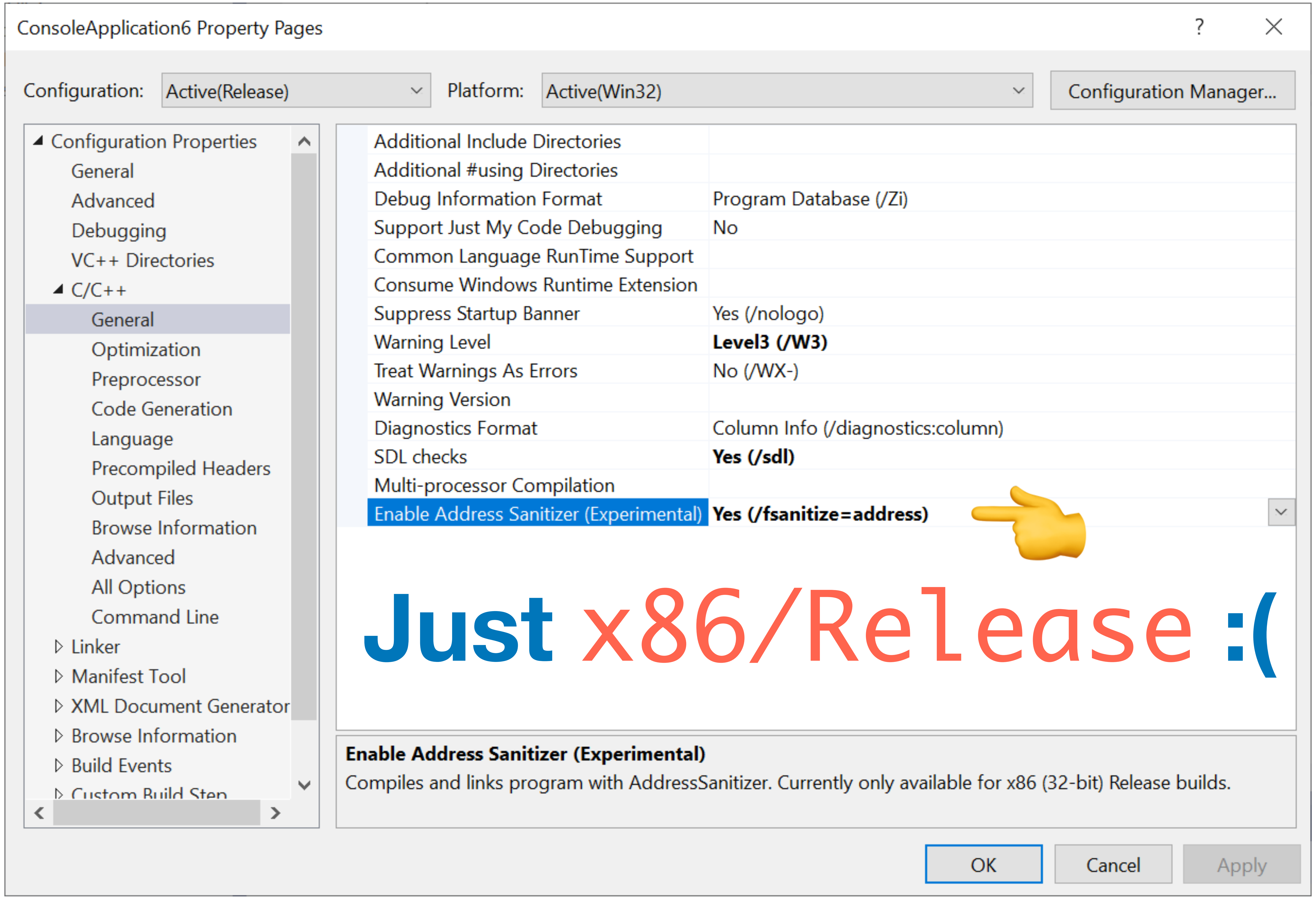
Visual Studio 2019

v16.4



Tech Preview

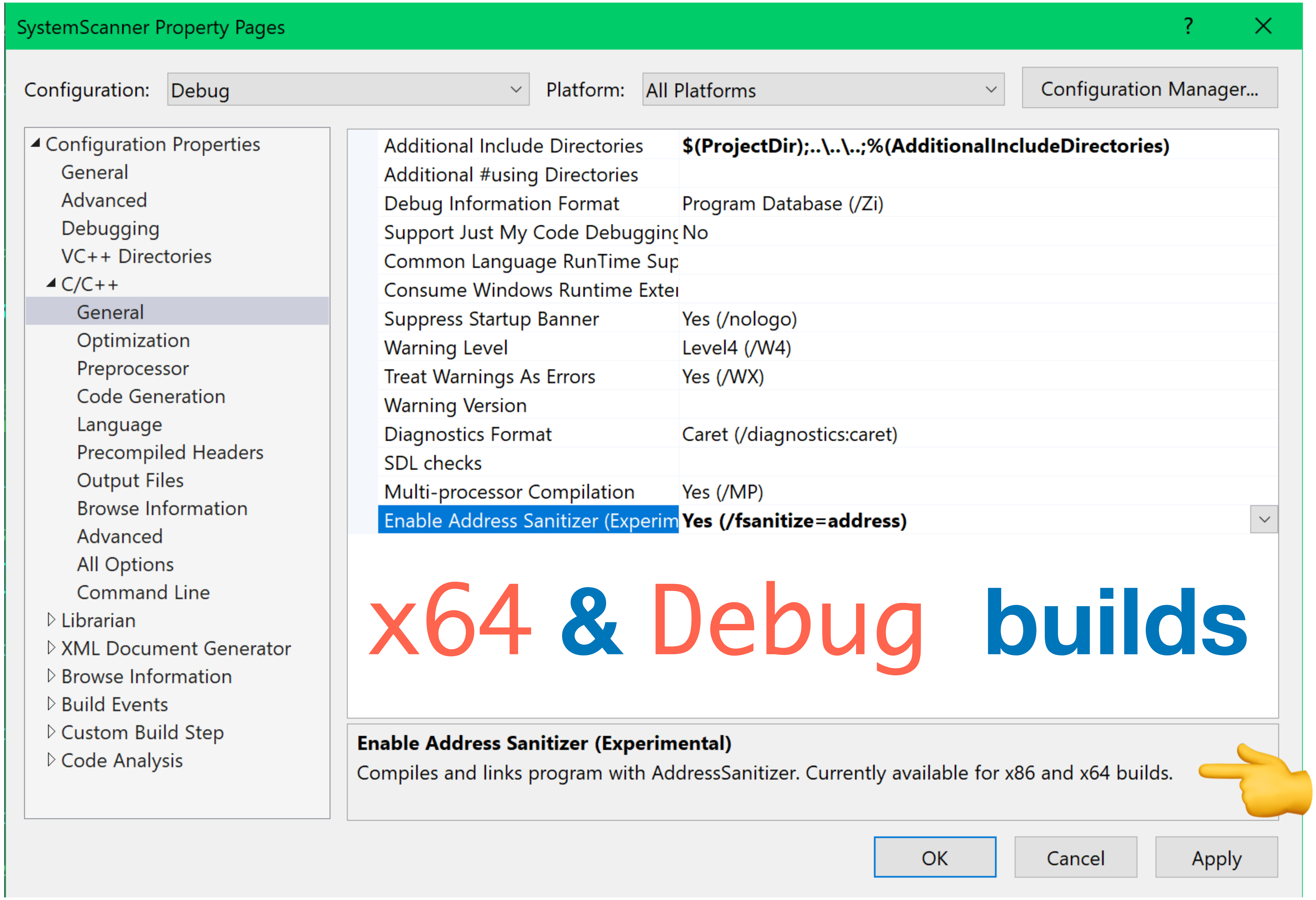
Visual Studio 2019 v16.4



October 2019

Visual Studio 2019
v16.7

August 2020



NEW

August 2020

Visual Studio 2019
v16.7

+ x64 & Debug builds

support all Debug runtimes: /MTd /MDd

docs.microsoft.com/en-us/visualstudio/releases/2019/release-notes#16.7.0

Visual Studio 2019

v16.7

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`

NEW

Soon...

Visual Studio 2019
v16.8

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`

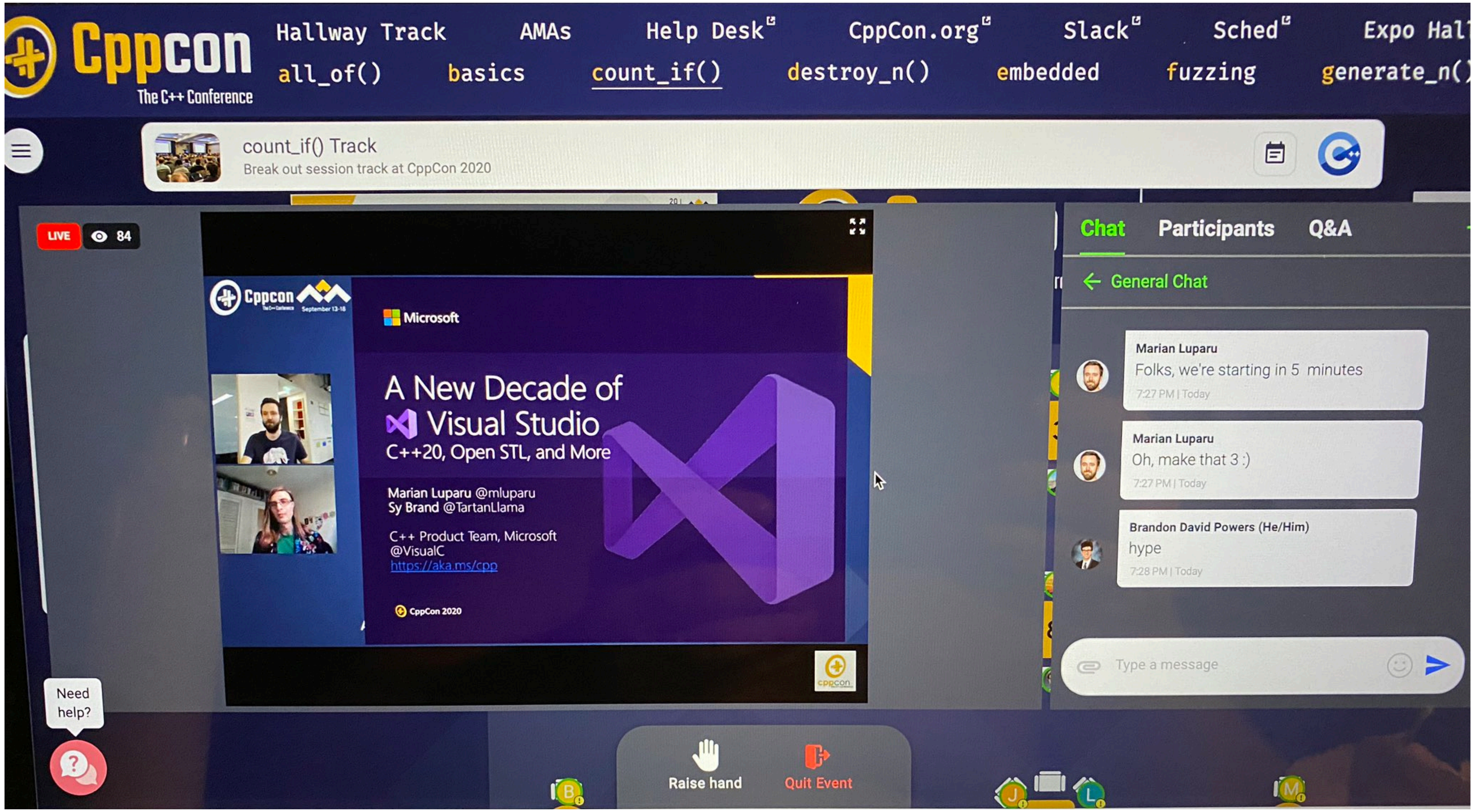
Future versions:

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

NEW

September 14

Visual Studio 2019
v16.8 Preview 3



devblogs.microsoft.com/cppblog/a-multitude-of-updates-in-visual-studio-2019-version-16-8-preview-3/

Visual Studio ASan

Experimental

Help needed: Report bugs!

Very soon out of `Experimental`

Visual Studio ASan

Experimental

Very tall order to bring ASAN to Windows

😅

Challenges bringing ASan to Windows

the surface area of the Microsoft platform is enormous

Challenges bringing ASan to Windows

the surface area of the Microsoft platform is enormous

non-standard C++

Challenges bringing ASan to Windows

the surface area of the Microsoft platform is enormous

non-standard C++

Challenges bringing ASan to Windows

the surface area of the Microsoft platform is enormous

non-standard C++

Structured Exception Handling (SEH) `/EHa`

Challenges bringing ASan to Windows

the surface area of the Microsoft platform is enormous

non-standard C++

Structured Exception Handling (SEH) `/EHa`

AV traps `0xc0000005`

Challenges bringing ASan to Windows

the surface area of the Microsoft platform is enormous

non-standard C++

Structured Exception Handling (SEH) `/EHa`

AV traps `0xc0000005`

vast amount of legacy code (really, really, really OLD code)

Challenges bringing ASan to Windows

the surface area of the Microsoft platform is enormous

non-standard C++

Structured Exception Handling (SEH) `/EHa`

AV traps `0xc0000005`

vast amount of legacy code (really, really, really OLD code)

COM

Challenges bringing ASan to Windows

the surface area of the Microsoft platform is enormous

non-standard C++

- Structured Exception Handling (SEH) `/EHa`
- AV traps `0xc0000005`
- vast amount of legacy code (really, really, really OLD code)
- COM
- Managed C++

Challenges bringing ASan to Windows

the surface area of the Microsoft platform is enormous

non-standard C++

- Structured Exception Handling (SEH) `/EHa`
- AV traps `0xc0000005`
- vast amount of legacy code (really, really, really OLD code)
- COM
- Managed C++
- ASan runtime interop with managed code (.NET)

Visual Studio ASan

`Experimental`

"Thank you" to `Microsoft` **team***

tirelessly working on this

🙏

2020: The Year of Sanitizers

Everyone will continue to invest heavily in this area (sanitizers)

just because it's **so effective** at just finding correctness issues

Microsoft has contributed back to LLVM
all the work they've done to make ASan runtime work on Windows

github.com/llvm/llvm-project/tree/master/compiler-rt

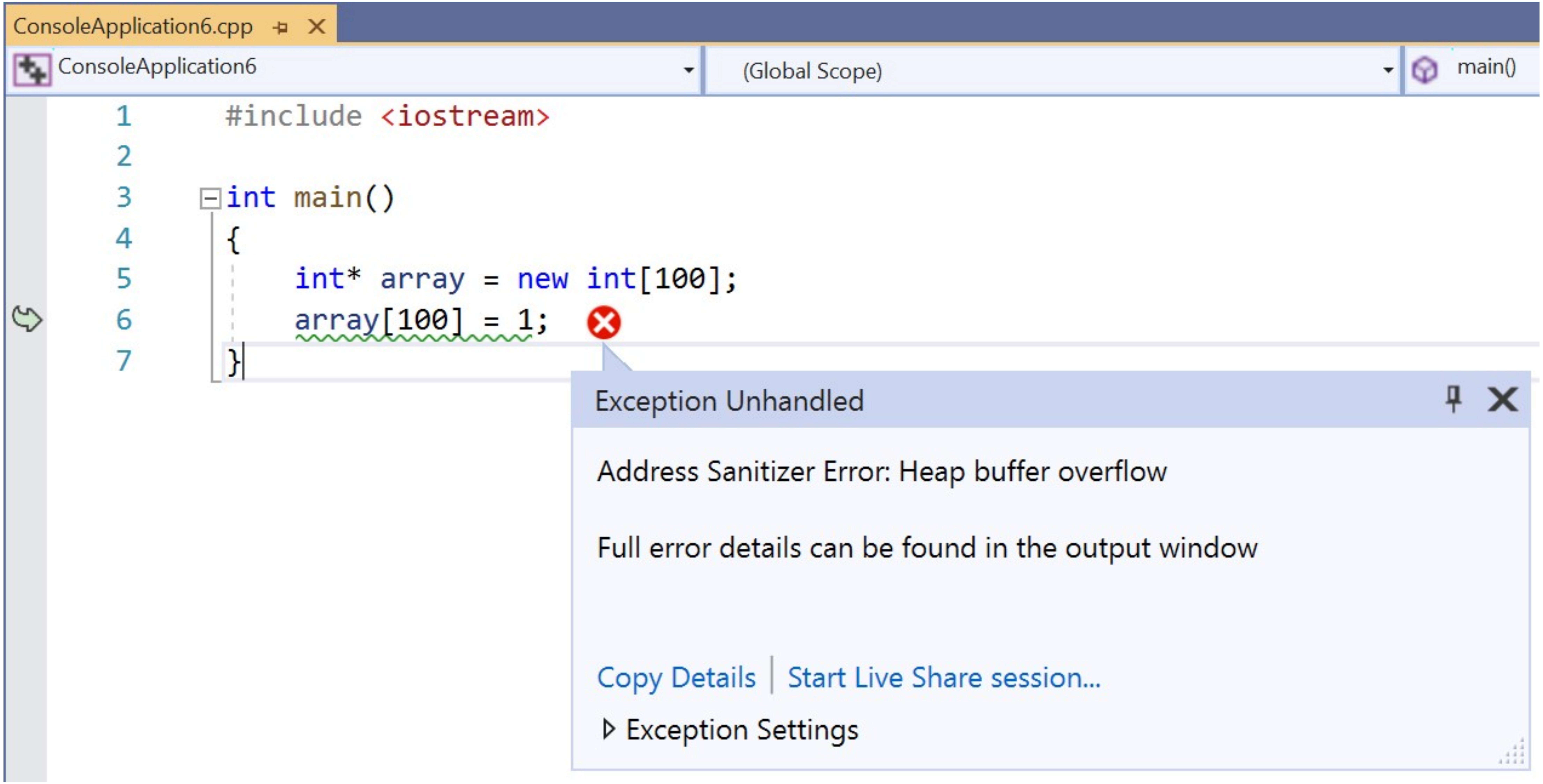
Visual Studio 2019

ASan Visual Studio integration:

- **MSBuild** & **CMake** support for both Windows & Linux
- **Debugger** integration for MSVC and Clang/LLVM

aka.ms/asan

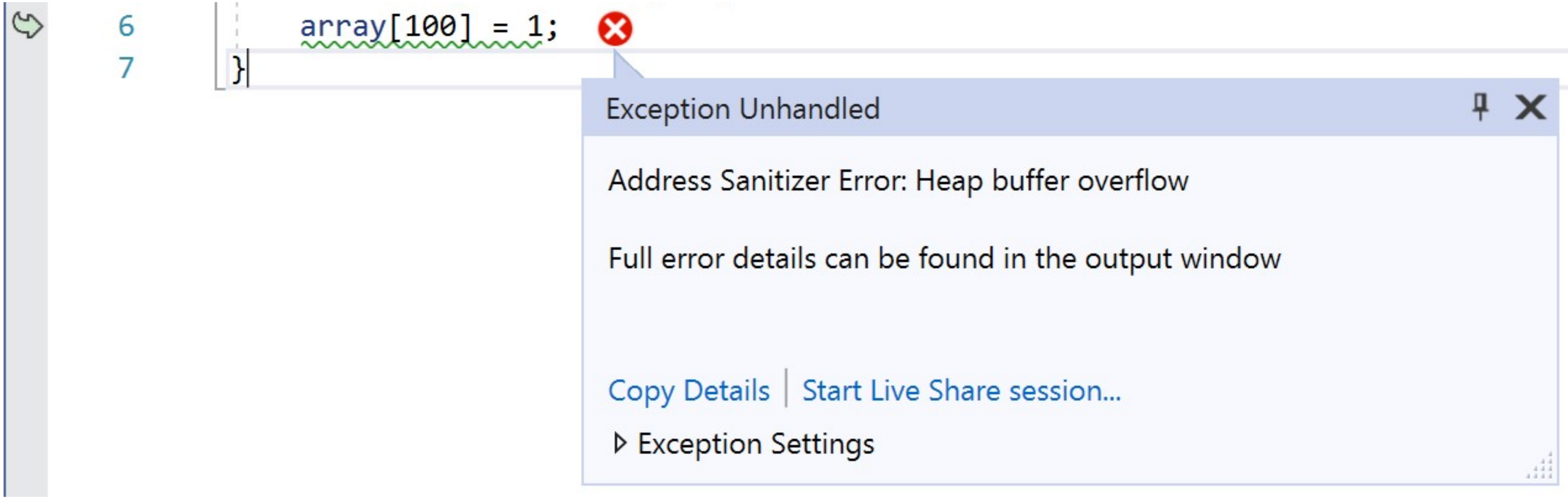
Address Sanitizer (ASan)



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

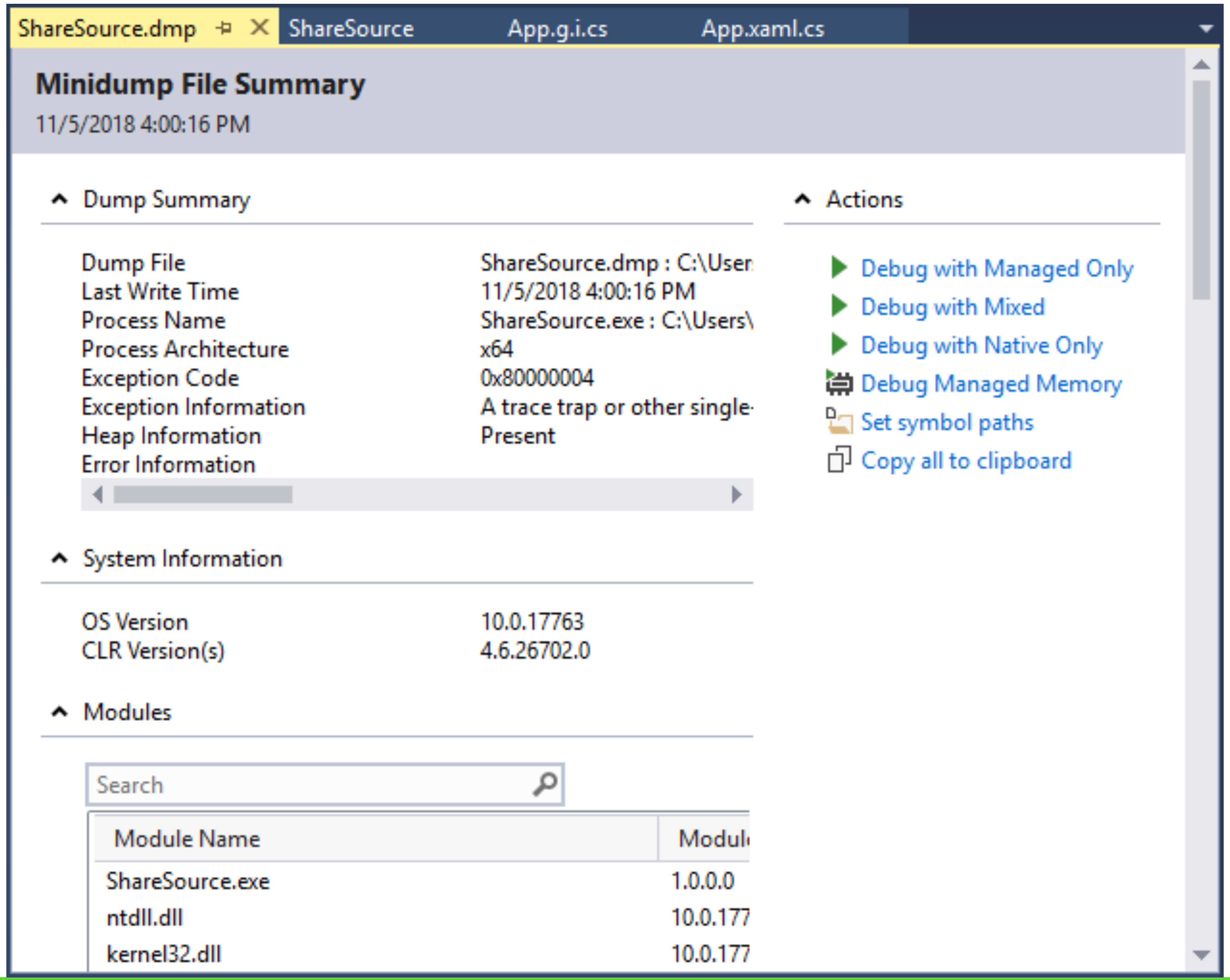
Game changer!

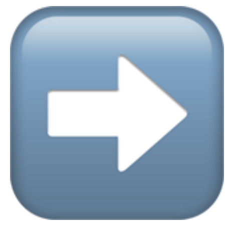
Minidump file (*.dmp) <= Windows snapshot process (program virtual memory/heap + metadata)

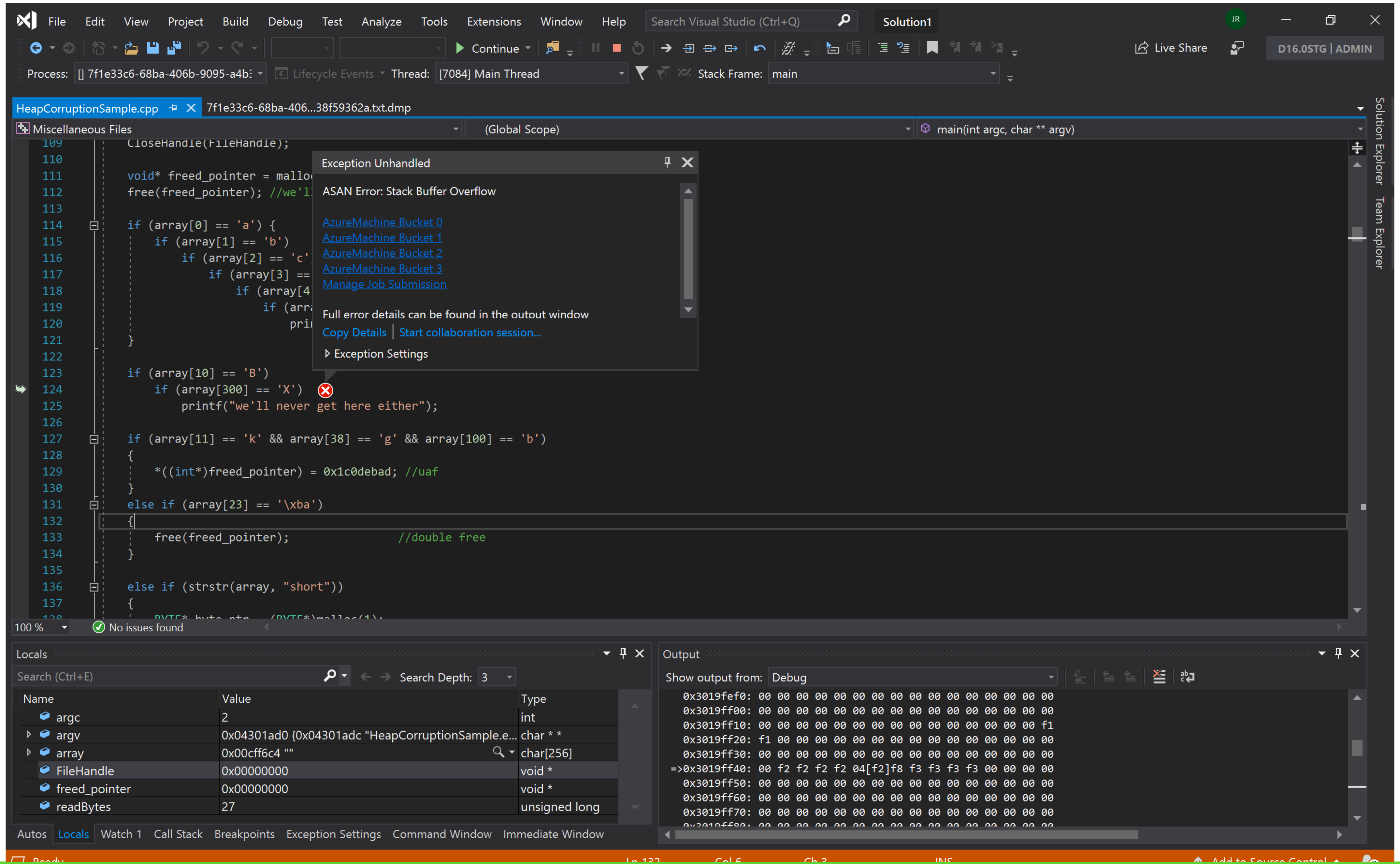
VS can parse & open this => Points at the location the error occurred.

+ Live Share

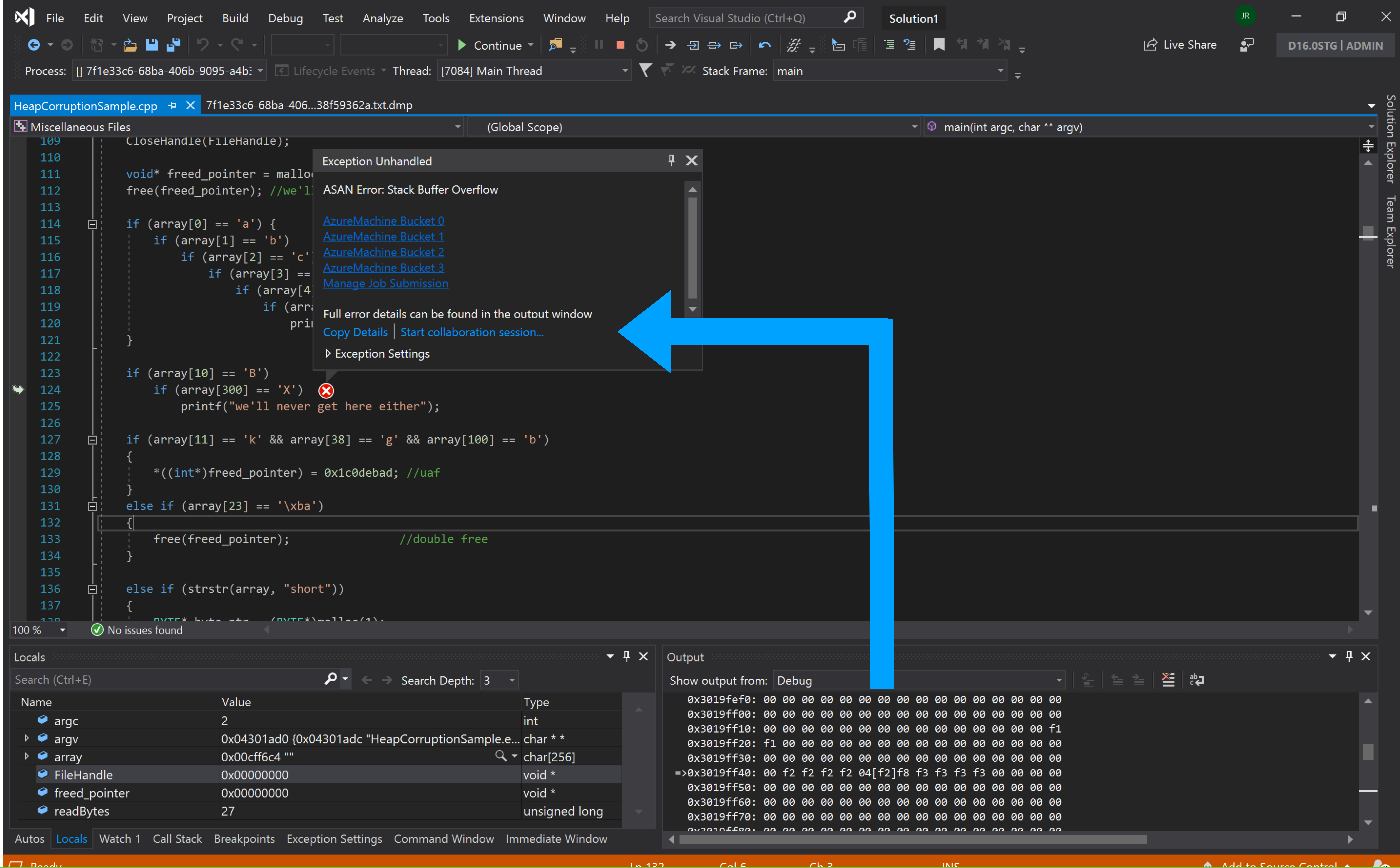
Changes the way you report a bug, in general







Snapshot Loaded



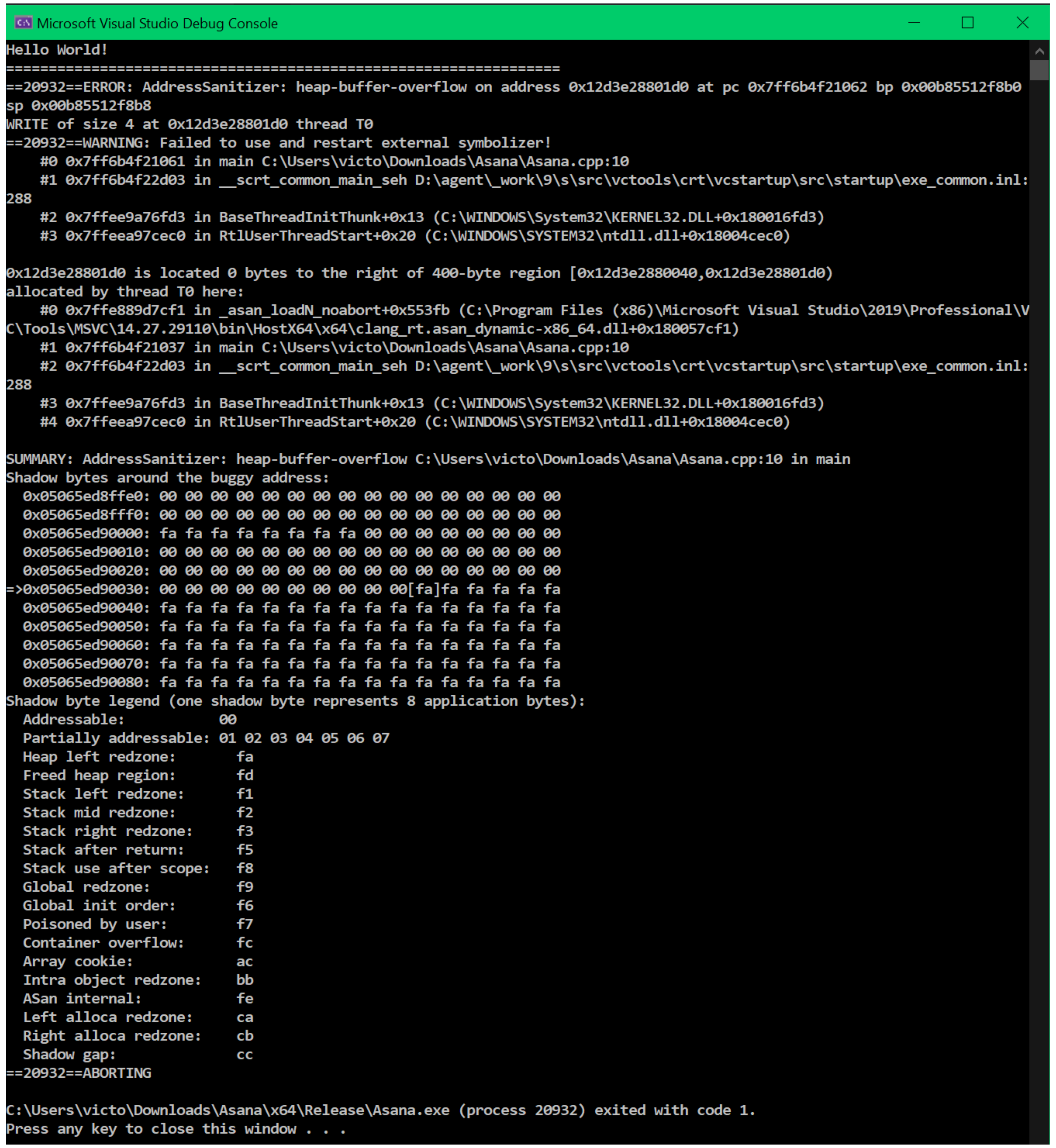
How does it work ?

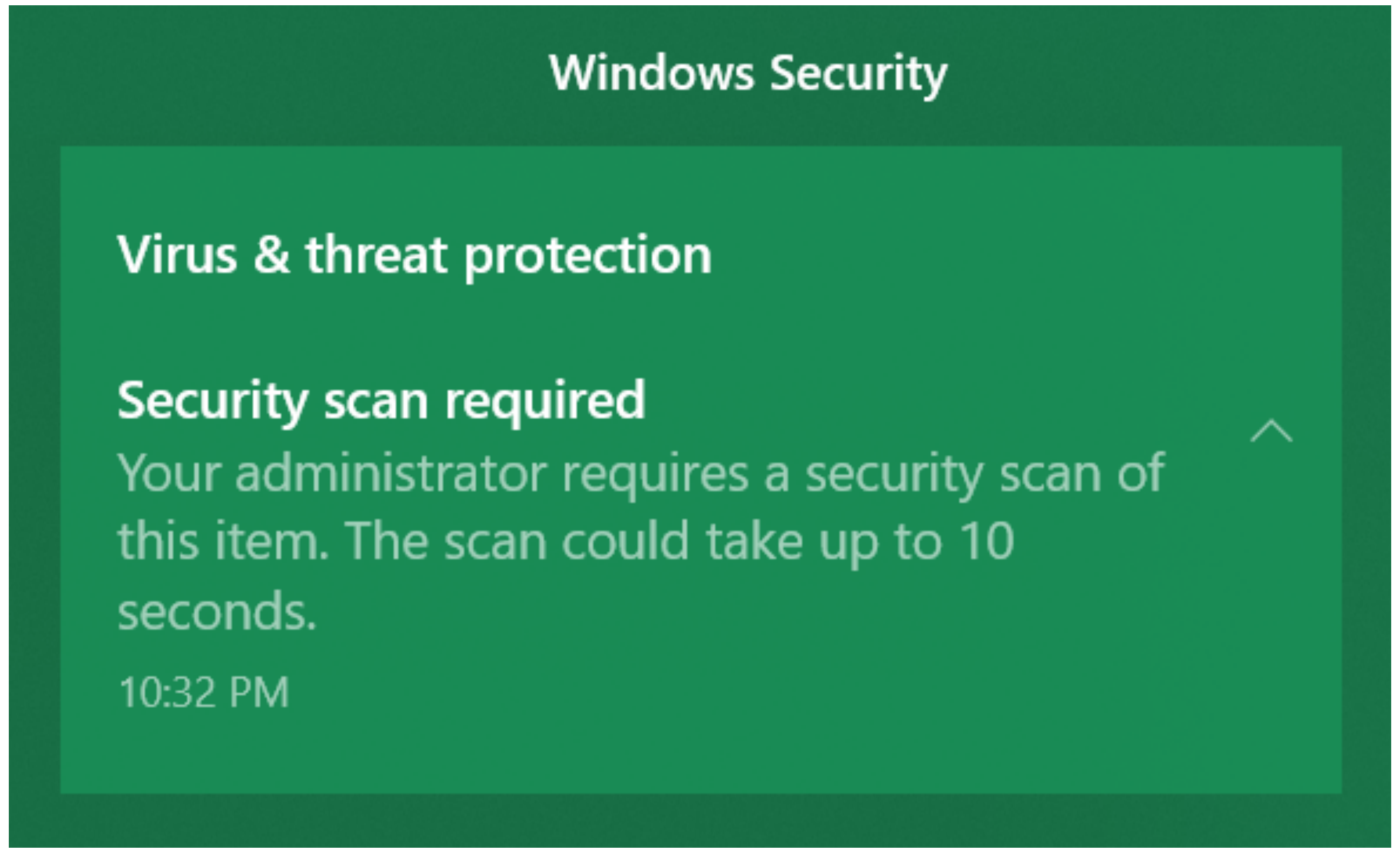
ASan is just Malware, used for Good

Microsoft Visual Studio Debug Console

```
Hello World!
=================================================================
==20932==ERROR: AddressSanitizer: heap-buffer-overflow on address 0x12d3e28801d0 at pc 0x7ff6b4f21062 bp 0x00b85512f8b0
sp 0x00b85512f8b8
WRITE of size 4 at 0x12d3e28801d0 thread T0
==20932==WARNING: Failed to use and restart external symbolizer!
    #0 0x7ff6b4f21061 in main C:\Users\victo\Downloads\Asana\Asana.cpp:10
    #1 0x7ff6b4f22d03 in __scrt_common_main_seh D:\agent\_work\9\s\src\vctools\crt\vcstartup\src\startup\exe_common.inl:
288
    #2 0x7ffee9a76fd3 in BaseThreadInitThunk+0x13 (C:\WINDOWS\System32\KERNEL32.DLL+0x180016fd3)
    #3 0x7ffeea97cec0 in RtlUserThreadStart+0x20 (C:\WINDOWS\SYSTEM32\ntdll.dll+0x18004cec0)

0x12d3e28801d0 is located 0 bytes to the right of 400-byte region [0x12d3e2880040,0x12d3e28801d0)
allocated by thread T0 here:
    #0 0x7ffe889d7cf1 in _asan_loadN_noabort+0x553fb (C:\Program Files (x86)\Microsoft Visual Studio\2019\Professional\V
C\Tools\MSVC\14.27.29110\bin\HostX64\x64\clang_rt.asan_dynamic-x86_64.dll+0x180057cf1)
    #1 0x7ff6b4f21037 in main C:\Users\victo\Downloads\Asana\Asana.cpp:10
    #2 0x7ff6b4f22d03 in __scrt_common_main_seh D:\agent\_work\9\s\src\vctools\crt\vcstartup\src\startup\exe_common.inl:
288
    #3 0x7ffee9a76fd3 in BaseThreadInitThunk+0x13 (C:\WINDOWS\System32\KERNEL32.DLL+0x180016fd3)
    #4 0x7ffeea97cec0 in RtlUserThreadStart+0x20 (C:\WINDOWS\SYSTEM32\ntdll.dll+0x18004cec0)

SUMMARY: AddressSanitizer: heap-buffer-overflow C:\Users\victo\Downloads\Asana\Asana.cpp:10 in main
Shadow bytes around the buggy address:
  0x05065ed8ffe0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x05065ed8fff0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x05065ed90000: fa fa fa fa fa fa fa fa 00 00 00 00 00 00 00 00
  0x05065ed90010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x05065ed90020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=>0x05065ed90030: 00 00 00 00 00 00 00 00 00 00[fa]fa fa fa fa fa
  0x05065ed90040: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x05065ed90050: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x05065ed90060: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x05065ed90070: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x05065ed90080: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
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
==20932==ABORTING

C:\Users\victo\Downloads\Asana\x64\Release\Asana.exe (process 20932) exited with code 1.
Press any key to close this window . . .
```

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
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
```

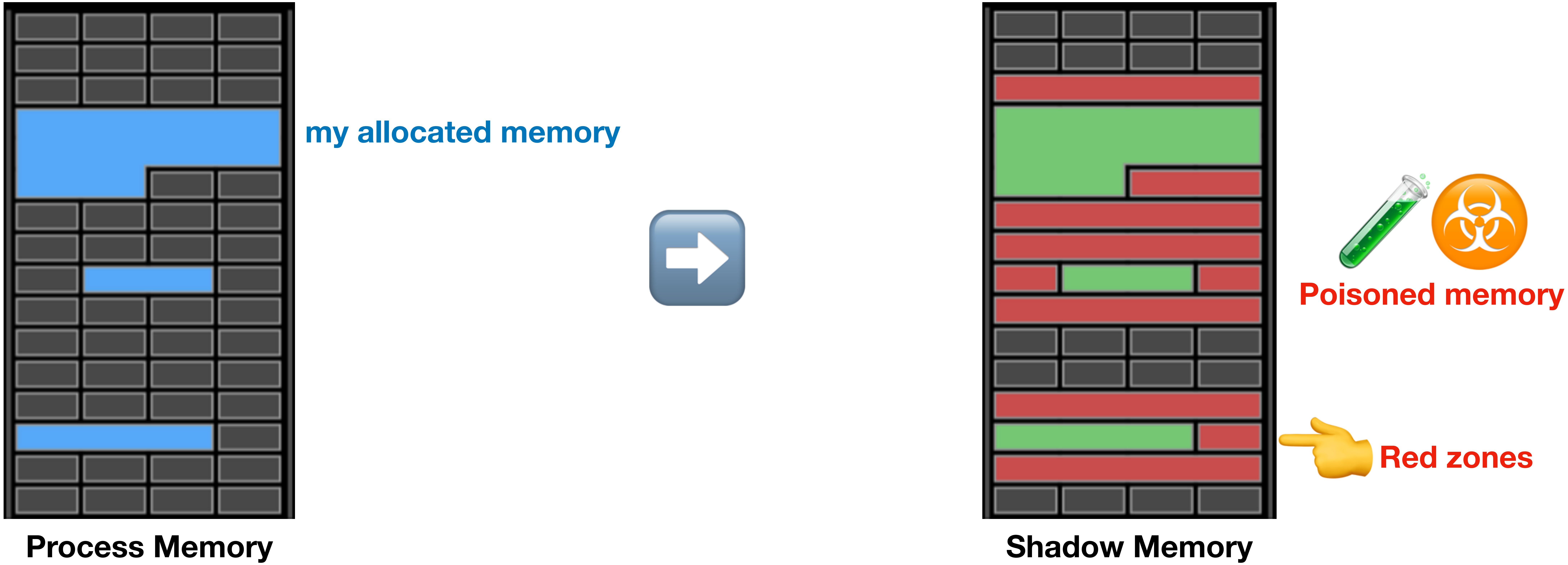
(of the 8 application bytes, how many are accessible)

issues & markers

Shadow byte legend

(one shadow byte represents 8 application bytes)

Shadow Mapping



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;
```

Stack use after scope

Code Generation
(simplified)

Lookups into shadow memory need to be very fast

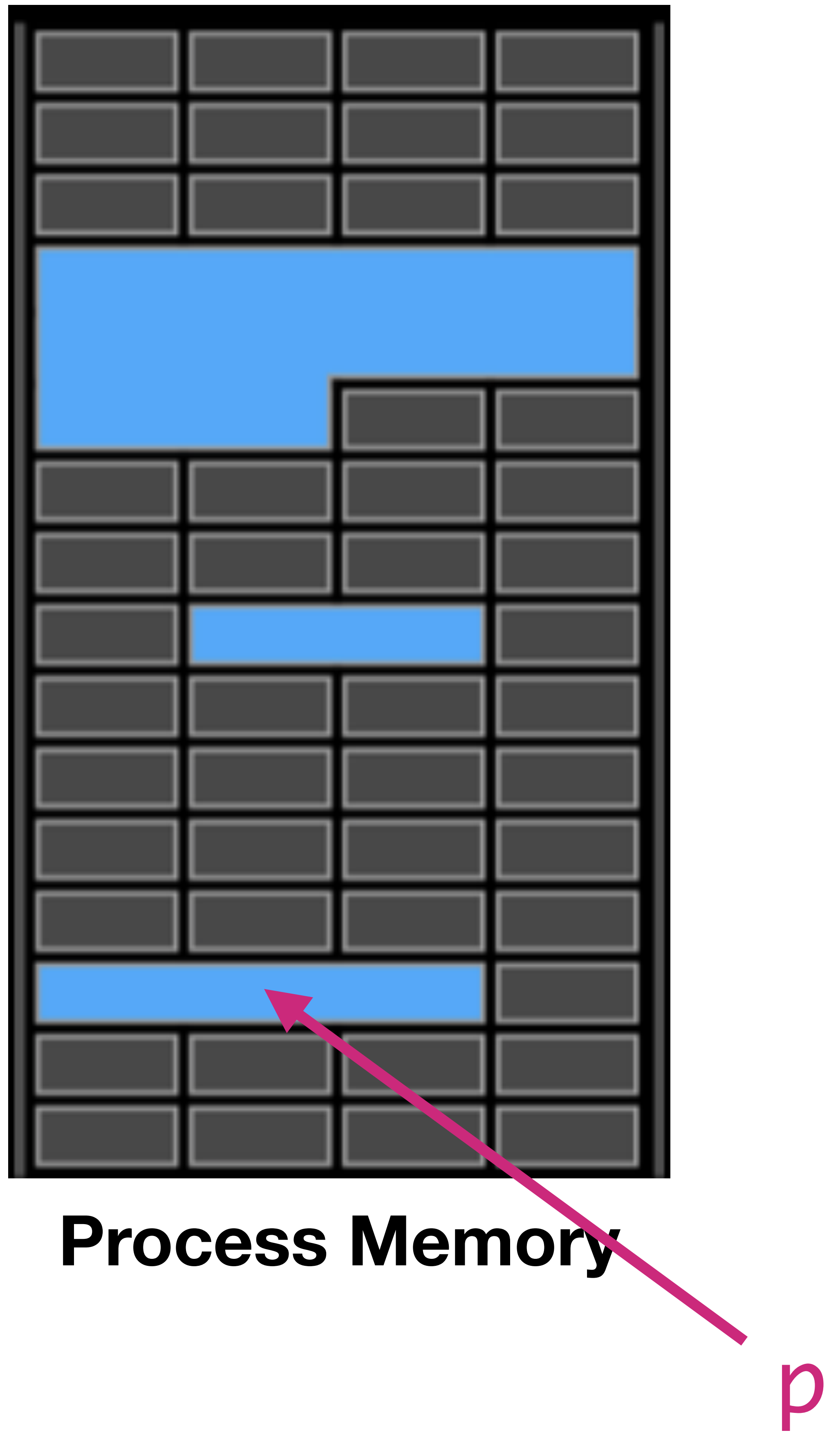
```
bool ShadowByte::IsBad(Addr) // is poisoned ?
{
  Shadow = Addr >> 3 + Offset;
  return (*Shadow) != 0;
}
```

Location of shadow region in memory

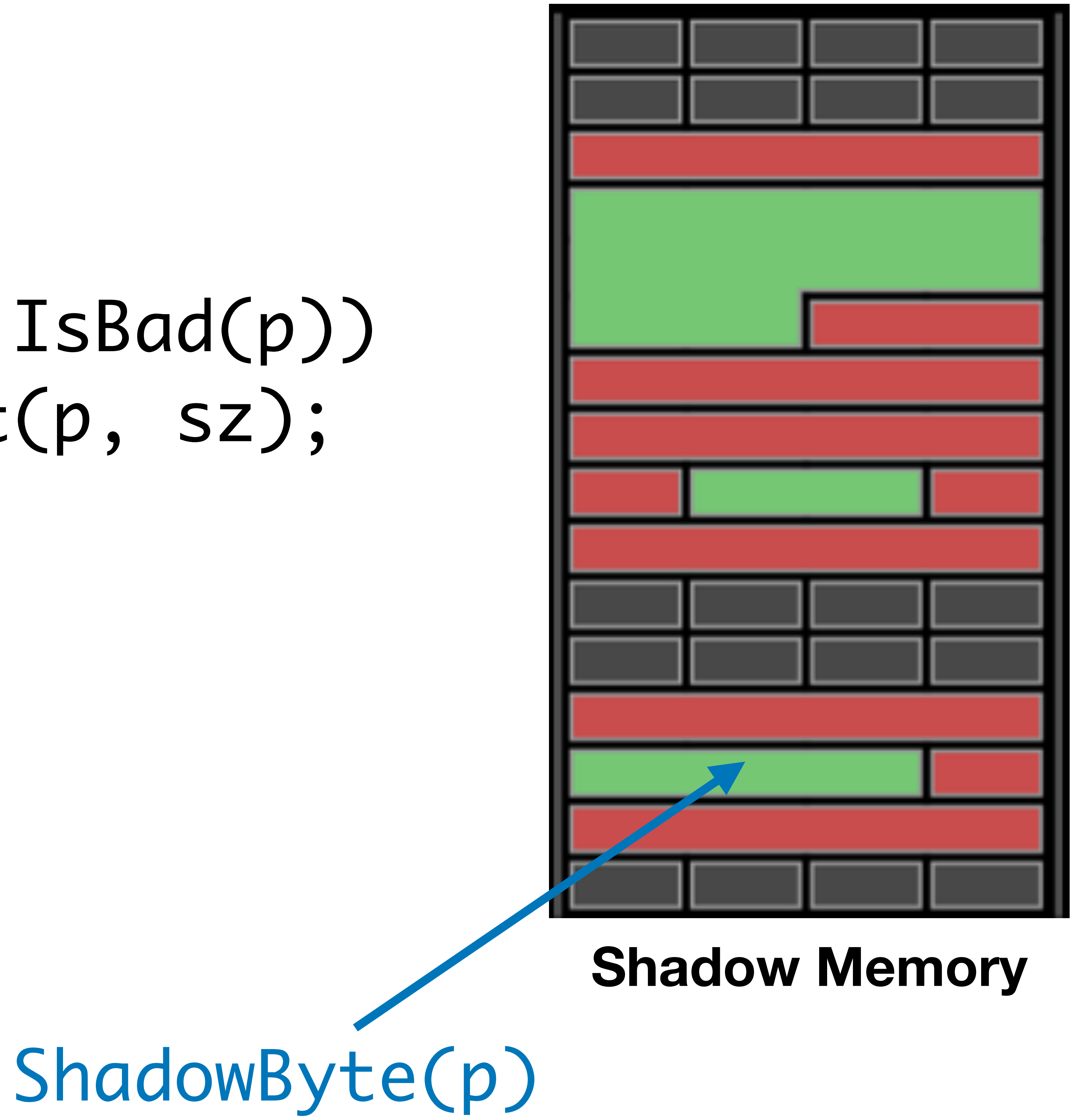
A Shadow Byte: `*( (User_Address >> 3) + 0x30000000 ) = 0xF8;`

`Stack use after scope`

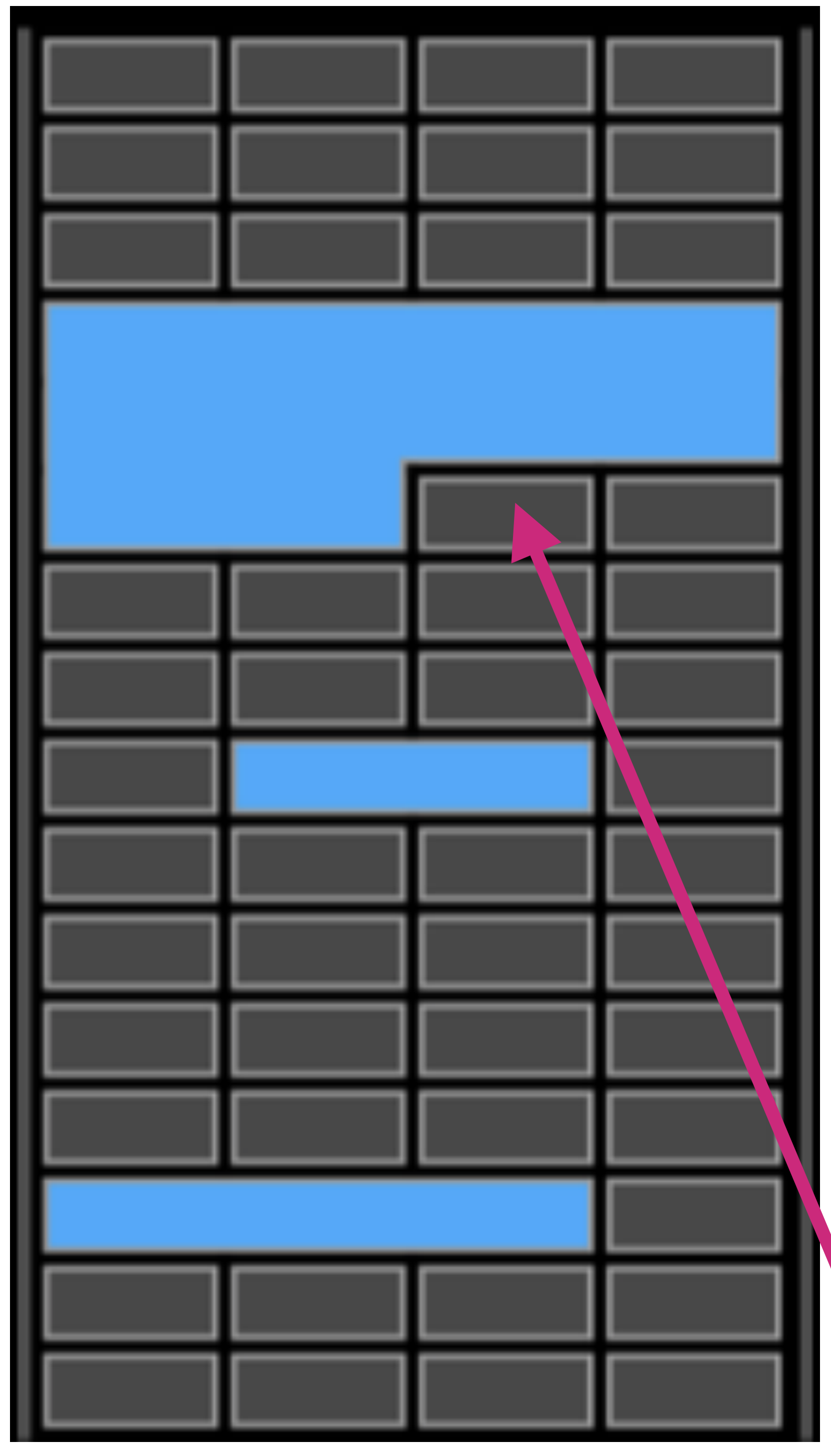
Shadow Mapping




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

*p = 0xf00d
```

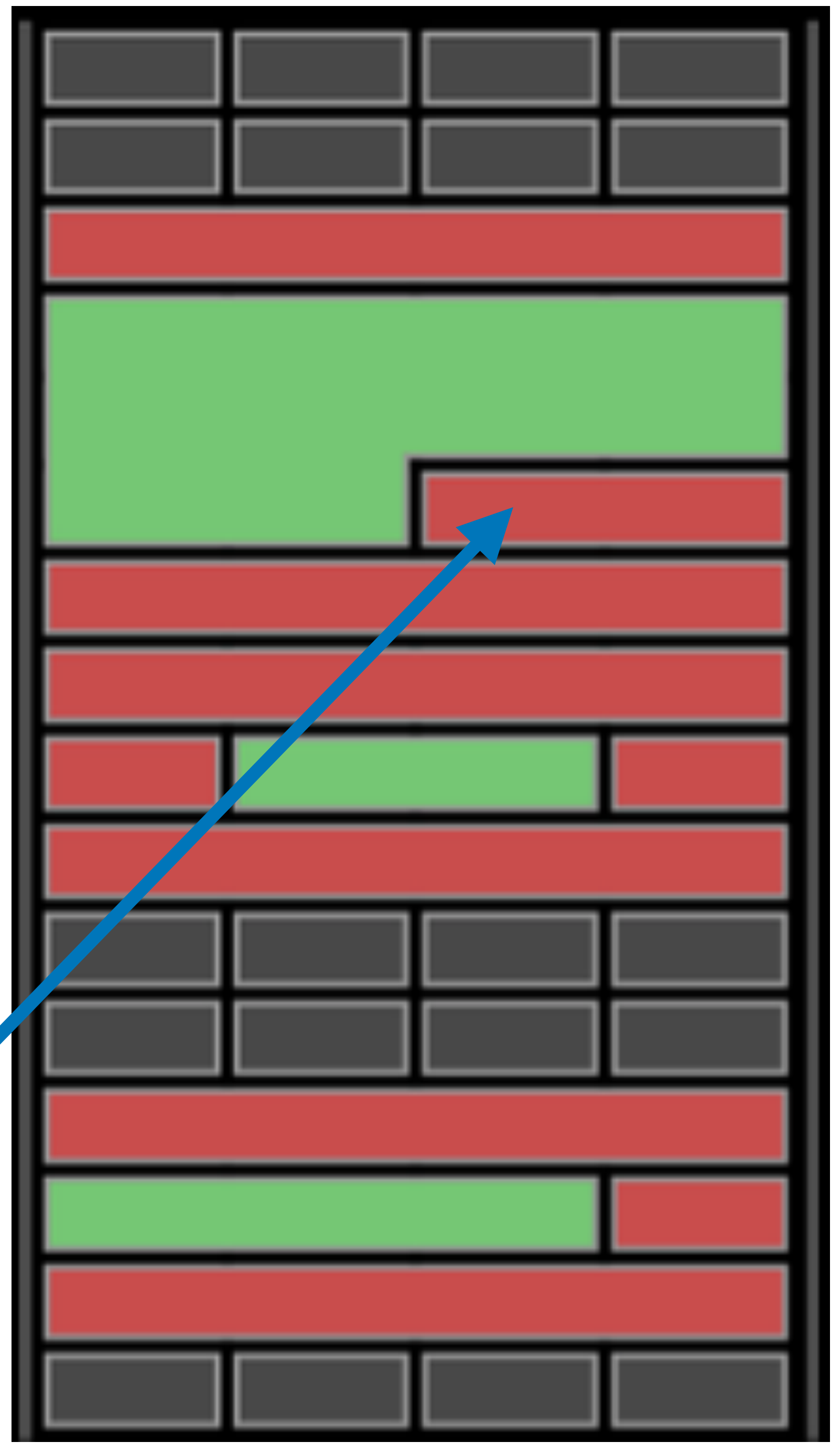


Shadow Mapping



Process Memory

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

*p = 0xbadf00d
```

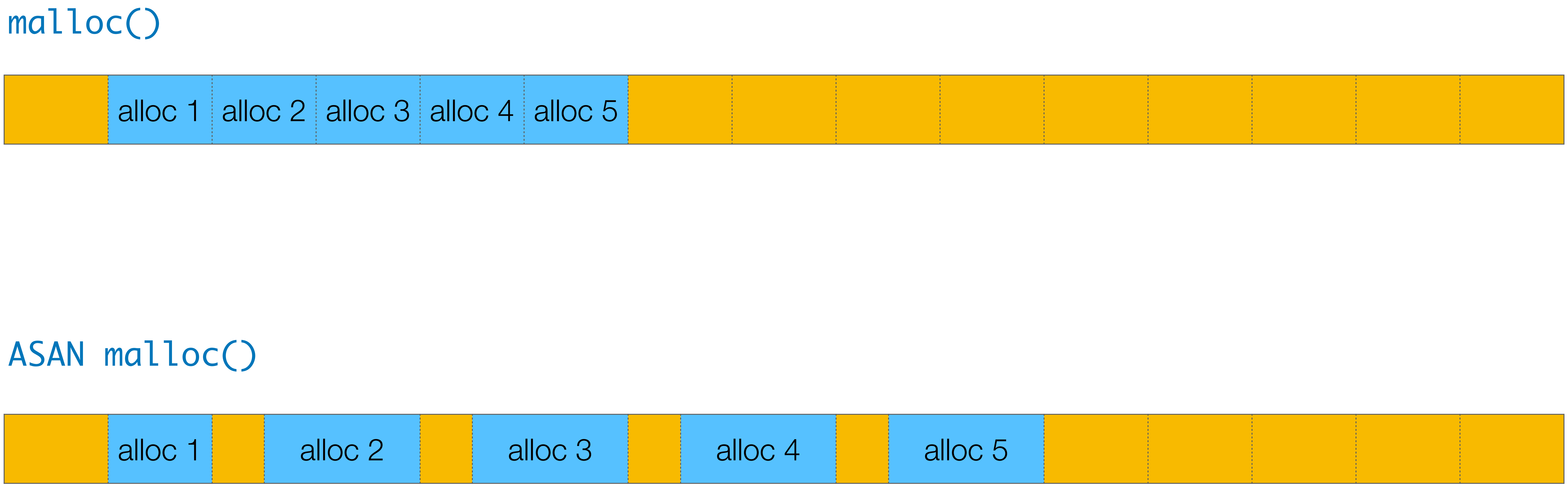


Shadow Memory

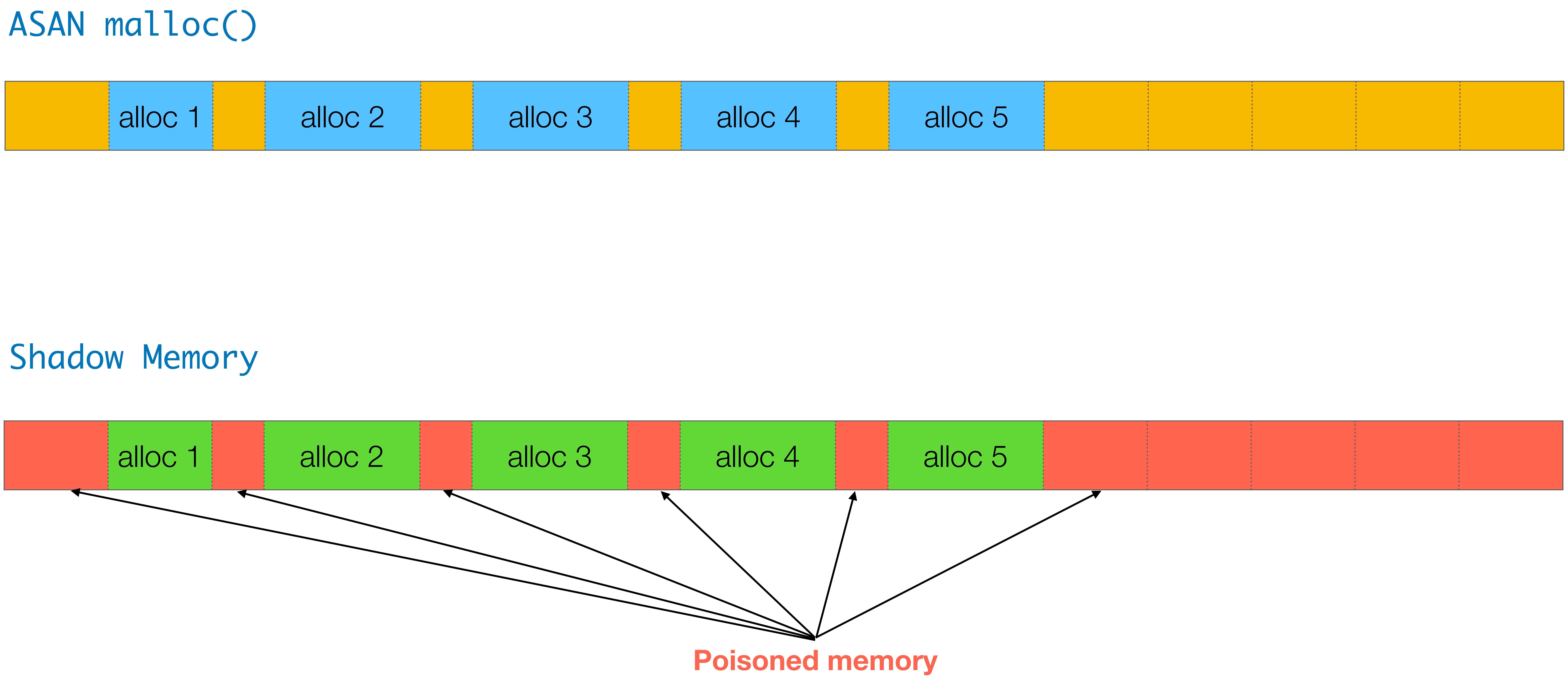
p

ShadowByte(p)

Heap Red Zones

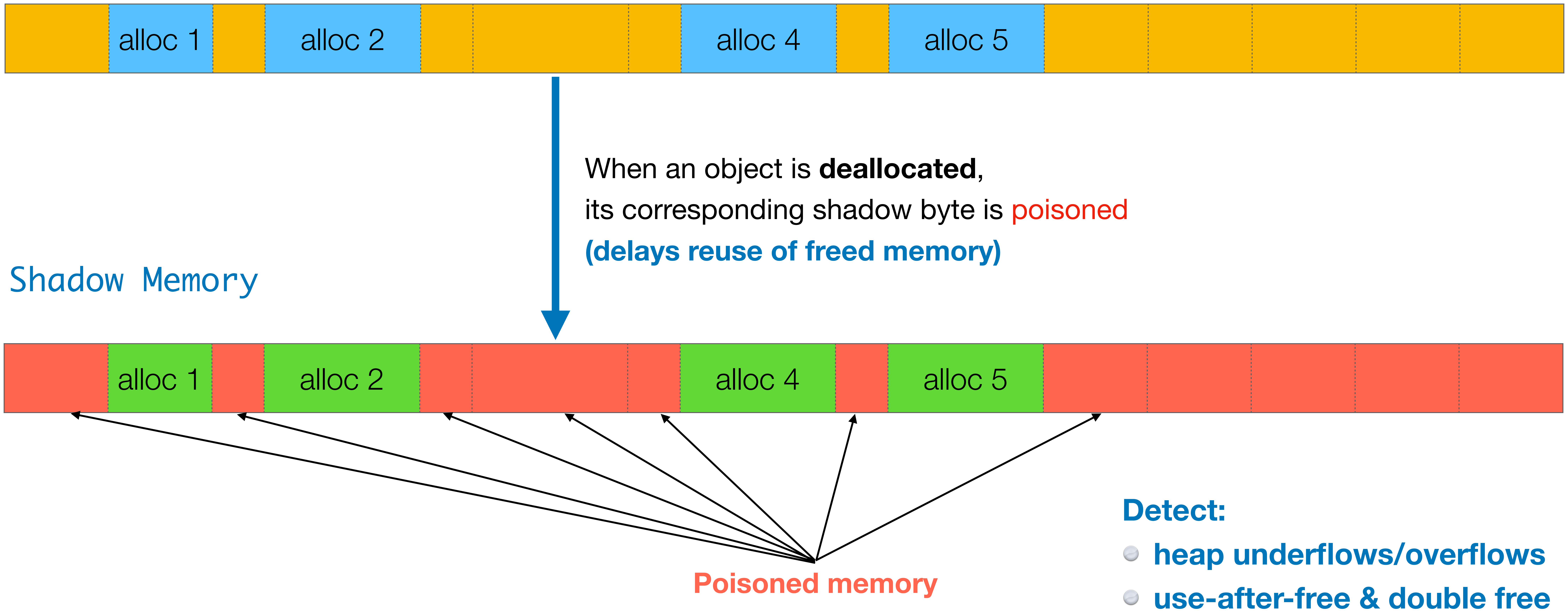


Heap Red Zones



Heap Red Zones

`ASAN malloc()`



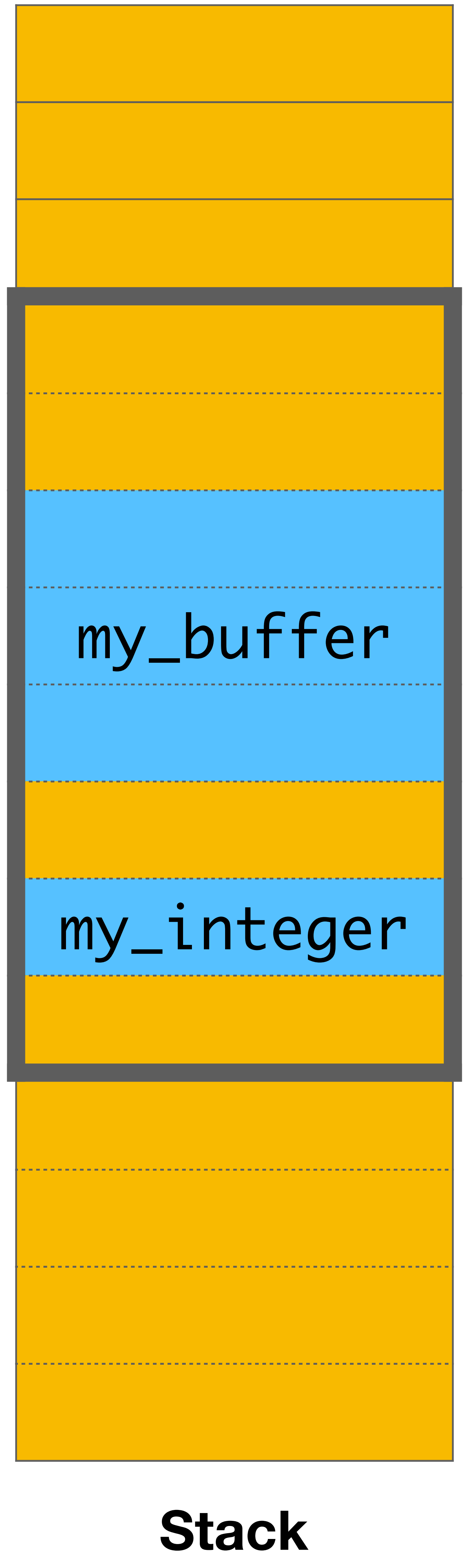
When an object is **deallocated**,
its corresponding shadow byte is poisoned
(delays reuse of freed memory)

`Shadow Memory`

Detect:

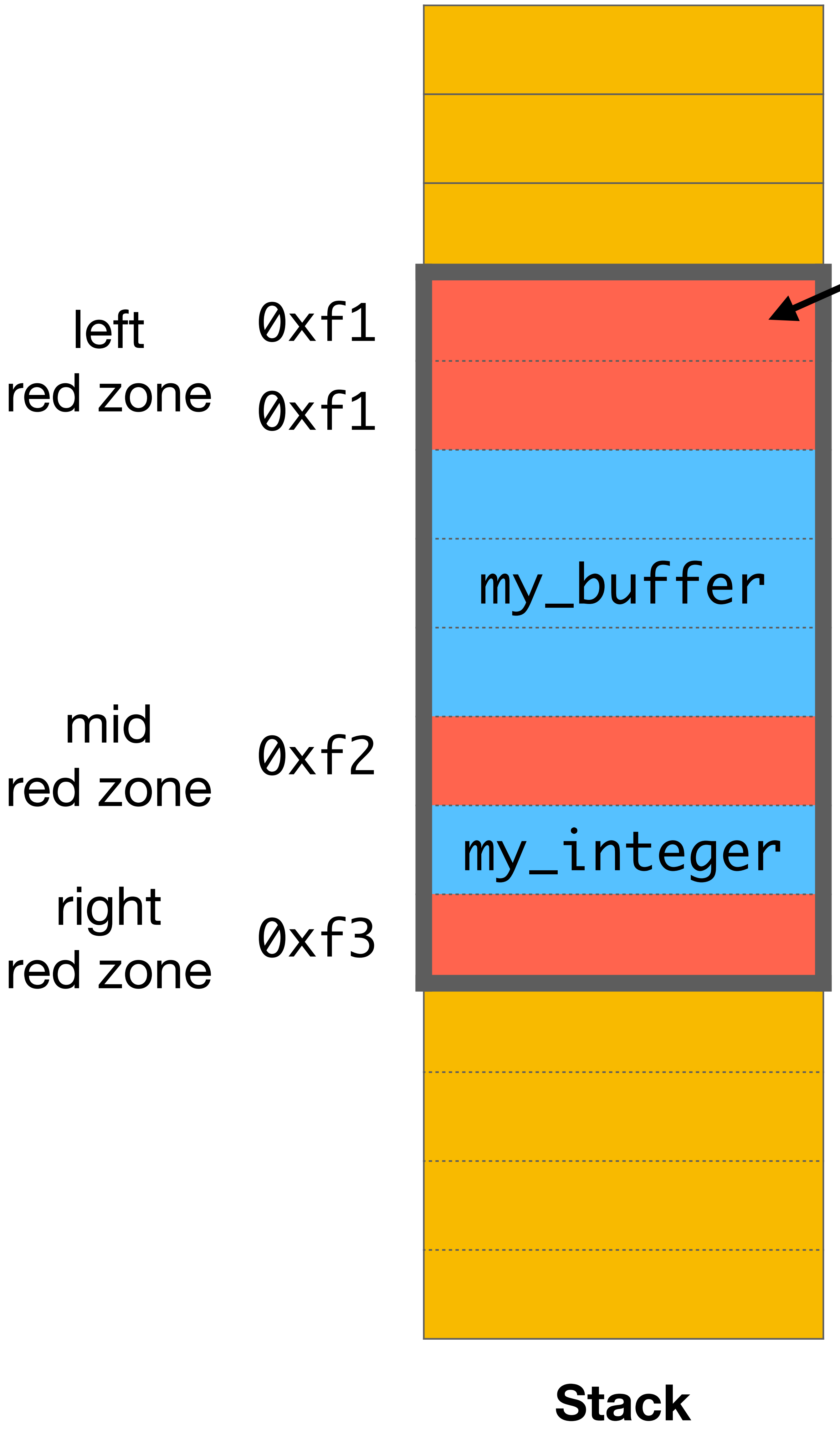
- **heap underflows/overflows**
- **use-after-free & double free**

Stack Red Zones




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

Stack Red Zones



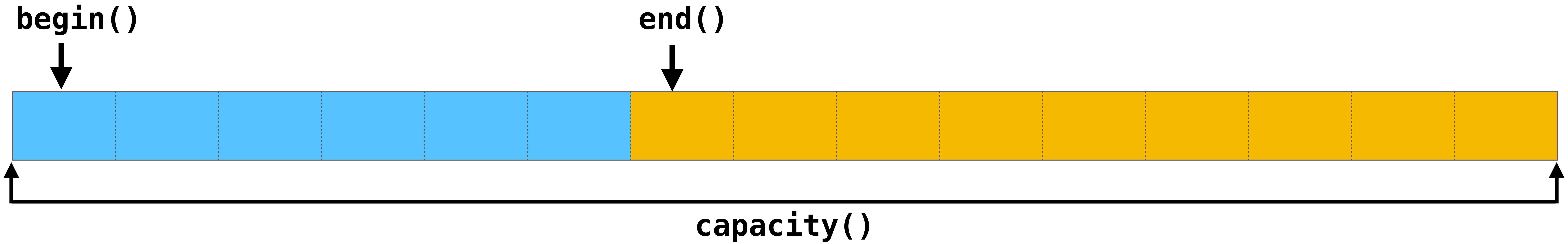
at runtime, the stack is **poisoned** when entering the function

```
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**

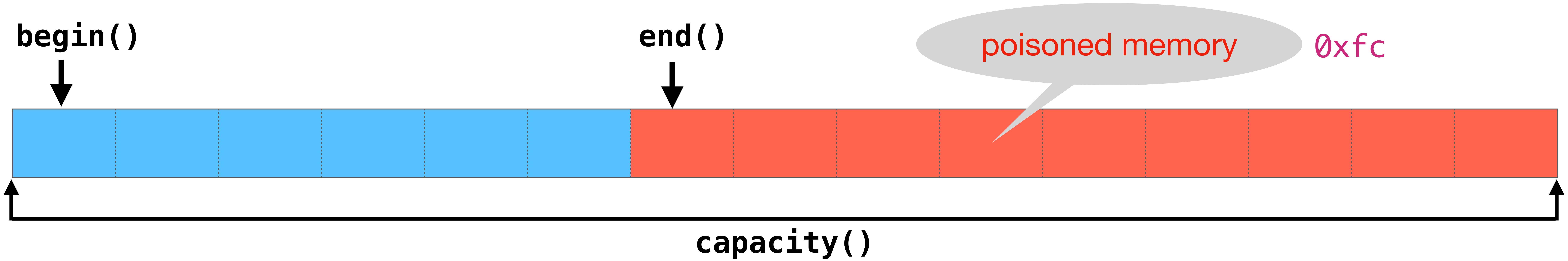
libc++

libstdc++

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

AddressSanitizer ContainerOverflow

`std::vector<T>`




```
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

VS 16.7.x**-16.8**.Preview

Compiling/linking from command-line

Manual CLI compile/link can be tedious,
be careful in choosing the correct **ASan libraries** to link against

Check here for all the details:

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

Eg.

- **Compiling a single static EXE**
  link the static runtime `asan-i386.lib` and the cxx library

- **Compiling an EXE with /MT runtime which will use ASan-instrumented DLLs**
  the EXE needs to have `asan-i386.lib` linked and
  the DLLs need the `clang_rt.asan_dll_thunk-i386.lib`

- **When compiling with the /MD dynamic runtime**
  all EXE and DLLs with instrumentation should be linked with
  `asan_dynamic-i386.lib` and `clang_rt.asan_dynamic_runtime_thunk-i386.lib`
  At runtime, these libraries will refer to the
  `clang_rt.asan_dynamic-i386.dll` shared ASan runtime.

/ZI
Edit and Continue (Debug)

```
error MSB8059:

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

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/

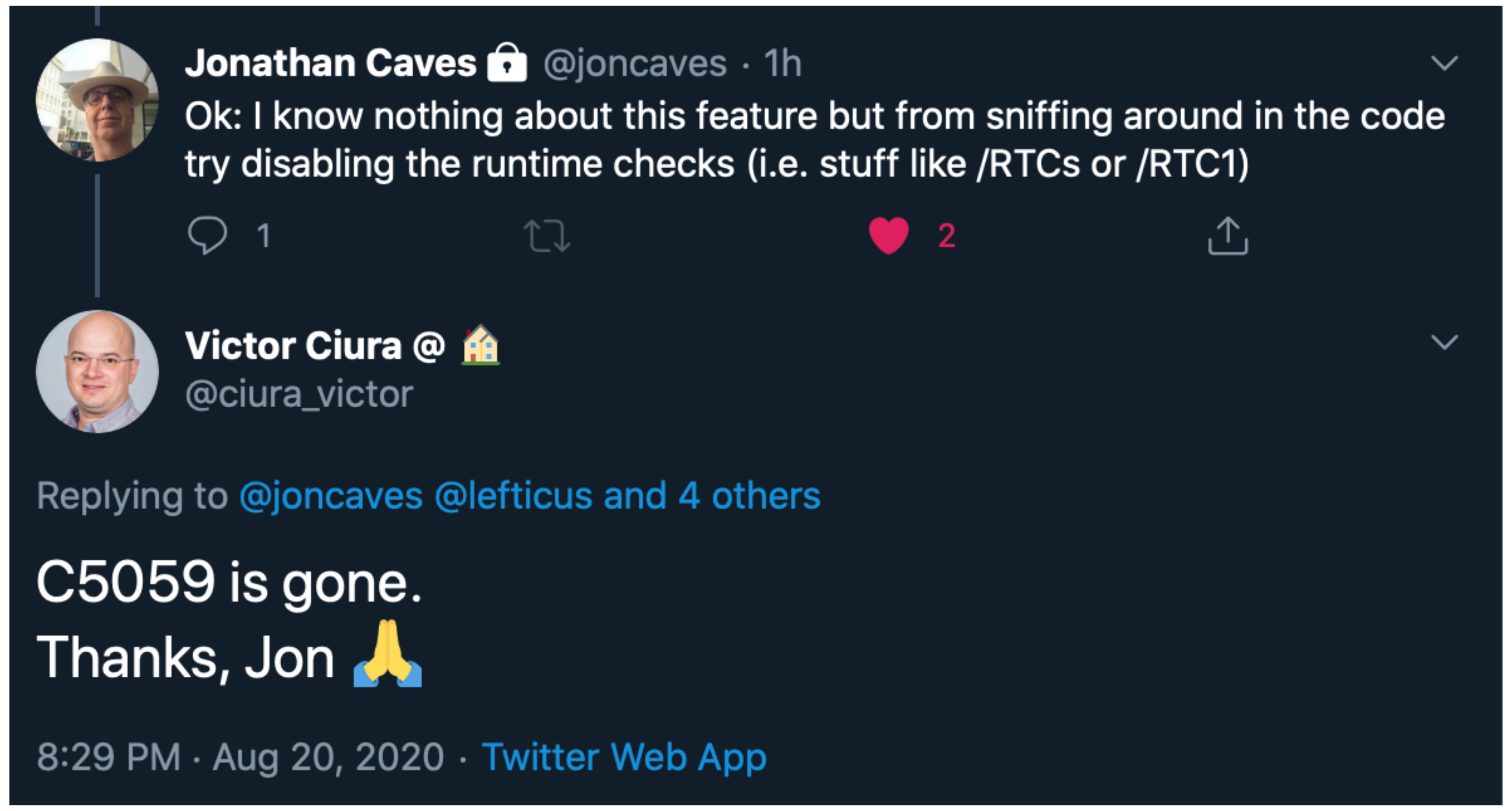
/RTCs and /RTC1 Runtime Checks

`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

Missing PDBs from VS

It appears some ASan runtime PDBs were not included in the VS installer:

```
[Debug]
vcasand.lib(vcasan.obj) : warning LNK4099: PDB 'vcasand.pdb' was not found with 'vcasand.lib(vcasan.obj)'
linking object as if no debug info


[Release]
vcasan.lib(vcasan.obj) : warning LNK4099: PDB 'vcasan.pdb' was not found with 'vcasan.lib(vcasan.obj)'
linking object as if no debug info
```

Building an EXE

Missing PDBs from VS

It appears some PDBs were not included in the VS installer:

```
[Debug]
libvcasand.lib(vcasan.obj) : warning LNK4099: PDB 'libvcasand.pdb' was not found with
'libvcasand.lib(vcasan.obj)


[Release]
libvcasan.lib(vcasan.obj) : warning LNK4099: PDB 'libvcasan.pdb' was not found with
'libvcasan.lib(vcasan.obj)'
```

Building a static LIB, linked into an EXE

vcasan(d).lib

- creates **metadata** the **IDE** will parse to support error reporting in its sub-panes
- metadata is stored in **.dmp** files produced when a program is terminated by ASan

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
```

MFC + 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

MFC + 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

📖 Explore Further

AddressSanitizer (ASan) for Windows with MSVC

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

AddressSanitizer for Windows: x64 and Debug Build Support

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

by Augustin Popa

@augustin_popa

Part III

Warm Fuzzy Feelings

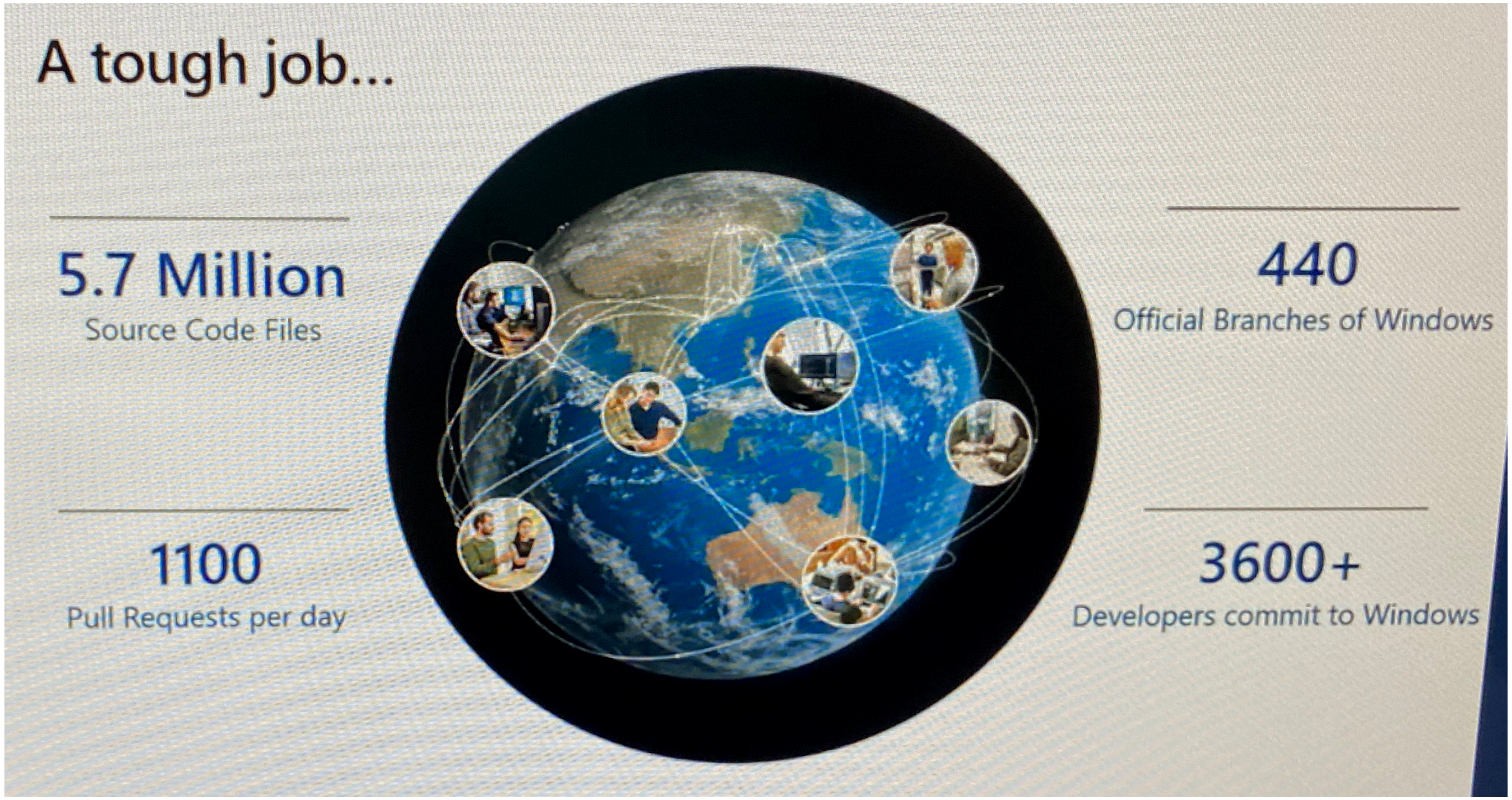
Sanitizers + Fuzzing

💪

Automatically generate inputs to you program to crash it.

Sanitizers + Fuzzing

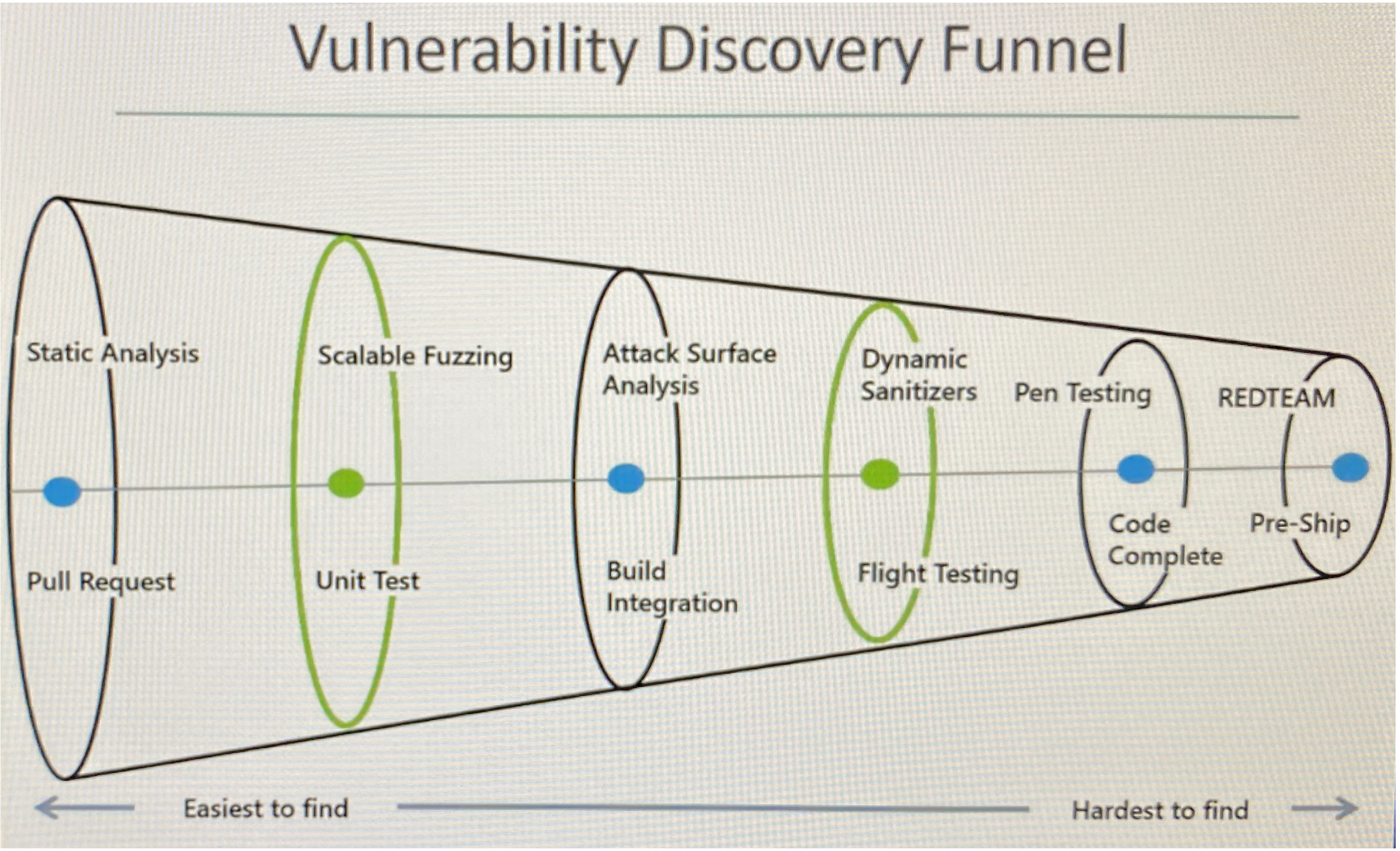
Case study at Microsoft Windows scale



https://sched.co/e7C0

Sanitizers + Fuzzing

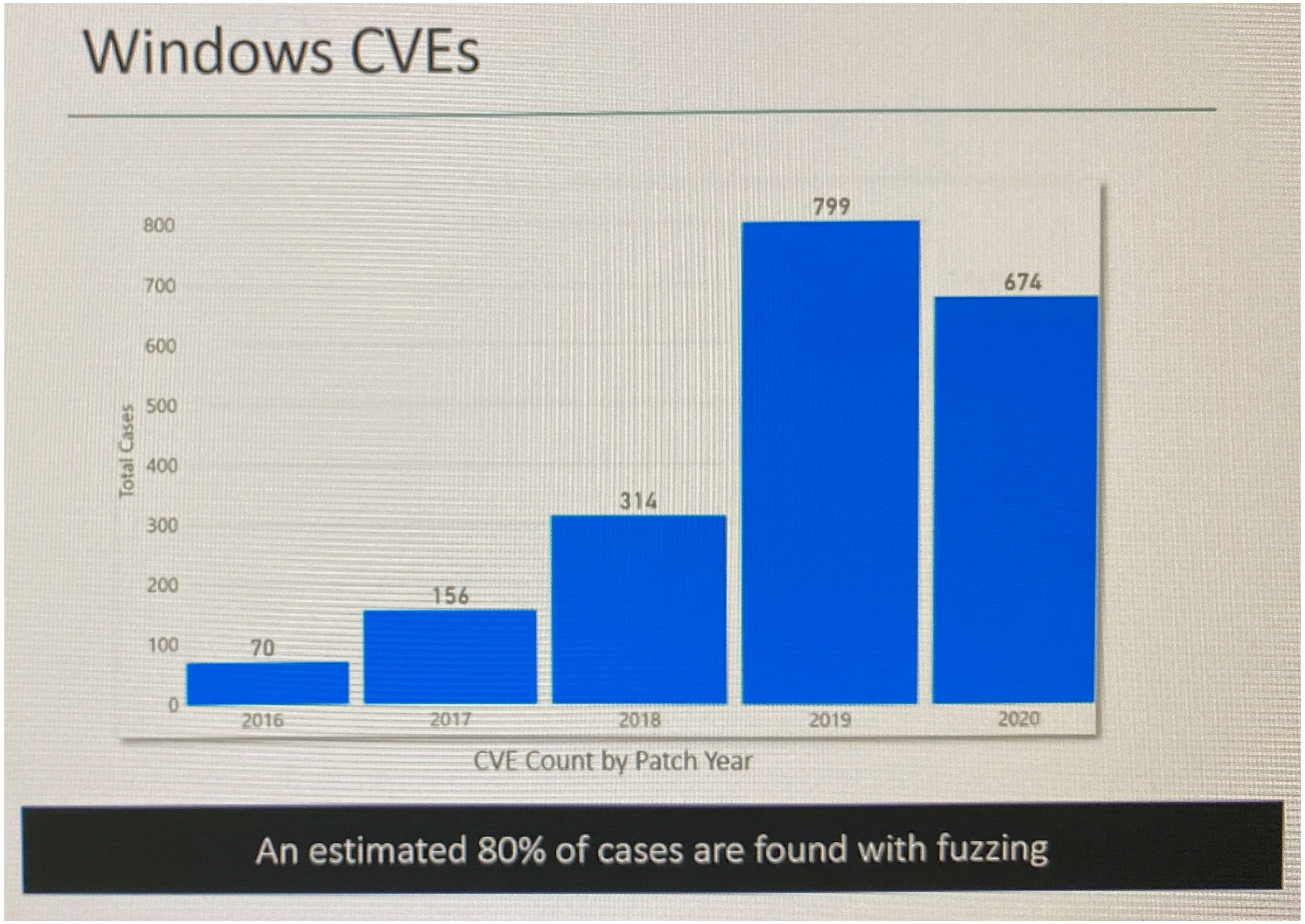
Case study at Microsoft Windows scale



https://sched.co/e7C0

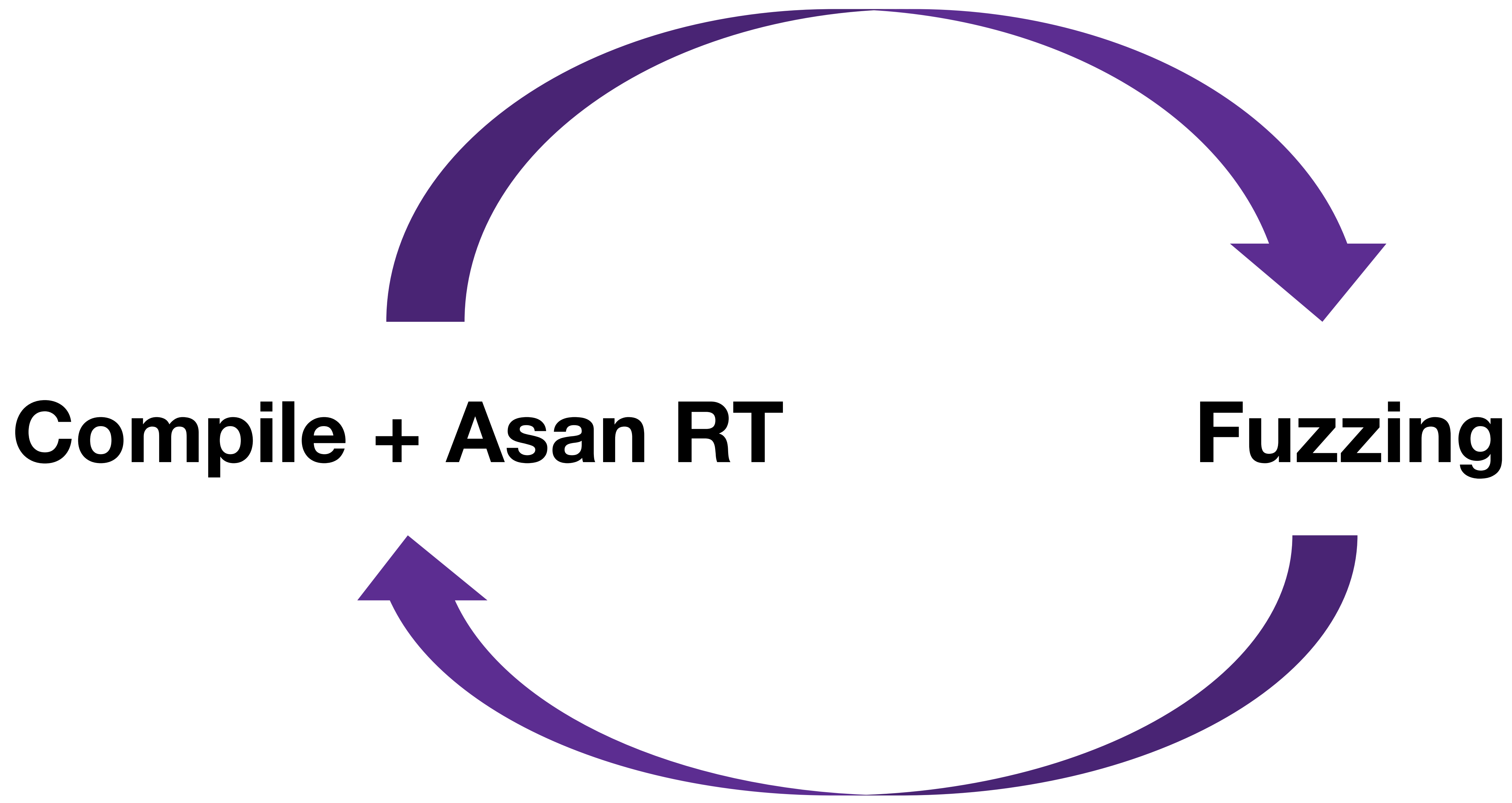
Sanitizers + Fuzzing

Case study at Microsoft Windows scale



https://sched.co/e7C0

Workflow



{ ASan + Fuzzing } => Azure

What is Microsoft Security Risk Detection?

Security Risk Detection is Microsoft's unique fuzz testing service for finding security critical bugs in software. Security Risk Detection helps customers quickly adopt practices and technology battle-tested over the last 15 years at Microsoft.

READ SUCCESS STORIES >

"Million dollar" bugs

Security Risk Detection uses "Whitebox Fuzzing" technology which discovered 1/3rd of the "million dollar" security bugs during Windows 7 development.

Battle tested tech

The same state-of-the-art tools and practices honed at Microsoft for the last decade and instrumental in hardening Windows and Office — with the results to prove it.

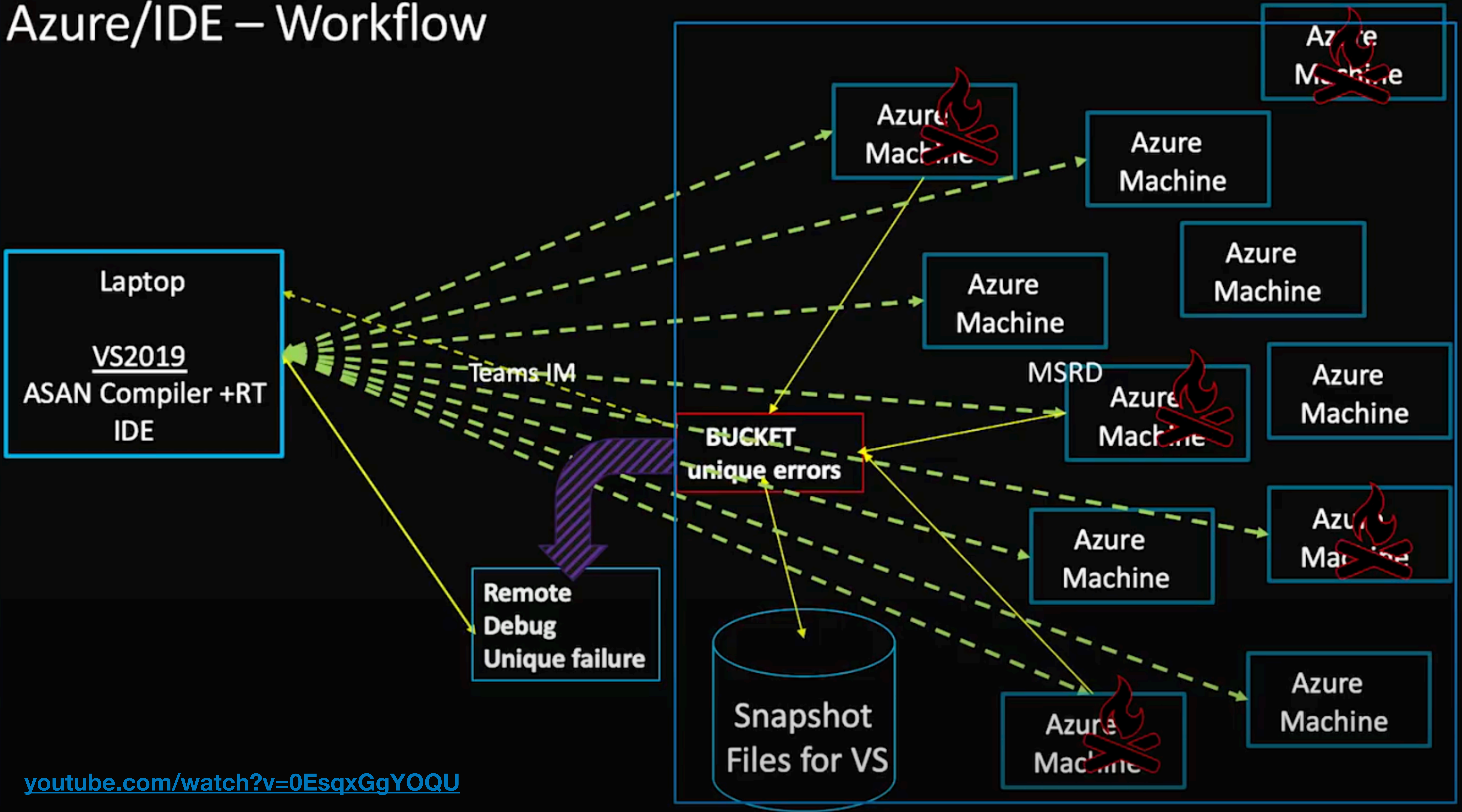
Scalable fuzz lab in the cloud

One click scalable, automated, Intelligent Security testing lab in the cloud.

Cross-platform support

Linux Fuzzing is now available. So, whether you're building or deploying software for Windows or Linux or both, you can utilize our Service.

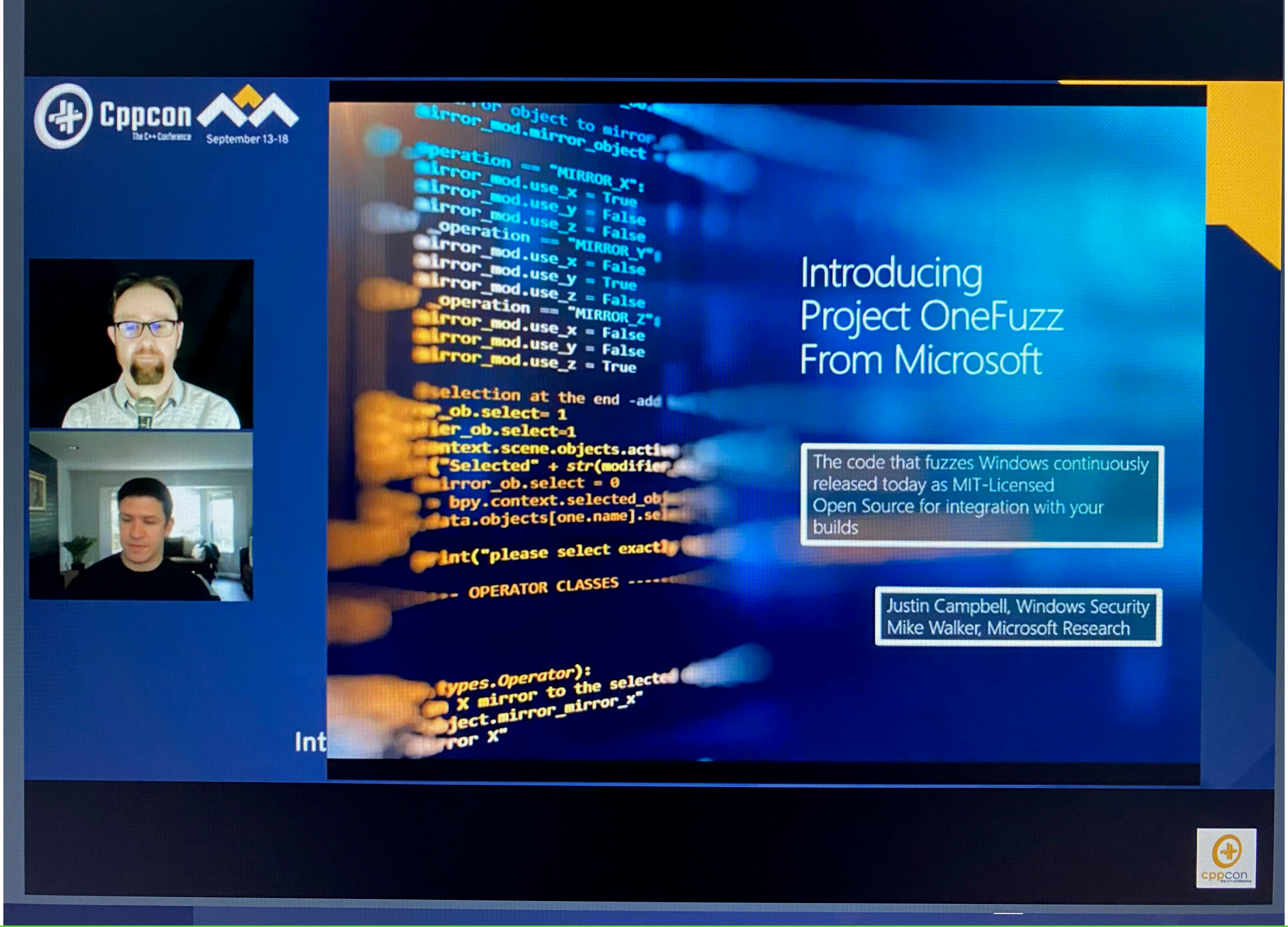
Azure/IDE – Workflow



youtube.com/watch?v=0EsqxGgYOQU

Microsoft OneFuzz

a platform you will be able to download from Github and run fuzzing on premise or in Azure


Cppcon
The C++ Conference
September 13-18
Introducing
Project OneFuzz
From Microsoft
The code that fuzzes Windows continuously
released today as MIT-Licensed
Open Source for integration with your
builds
Justin Campbell, Windows Security
Mike Walker, Microsoft Research

1 week ago

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:

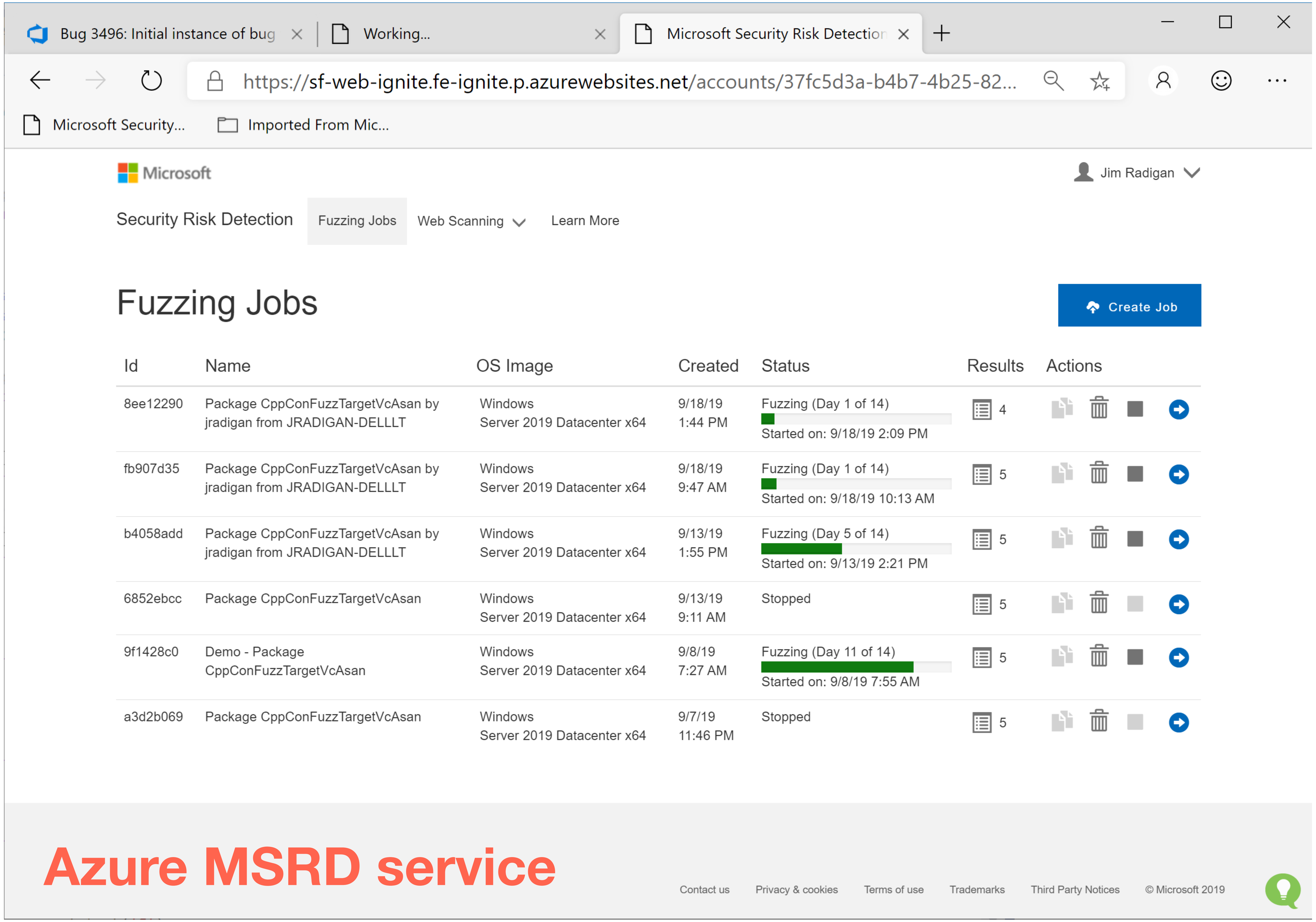
- **Teams**
- **ADO work items**

Azure DevOps Pipeline

GitHub Actions

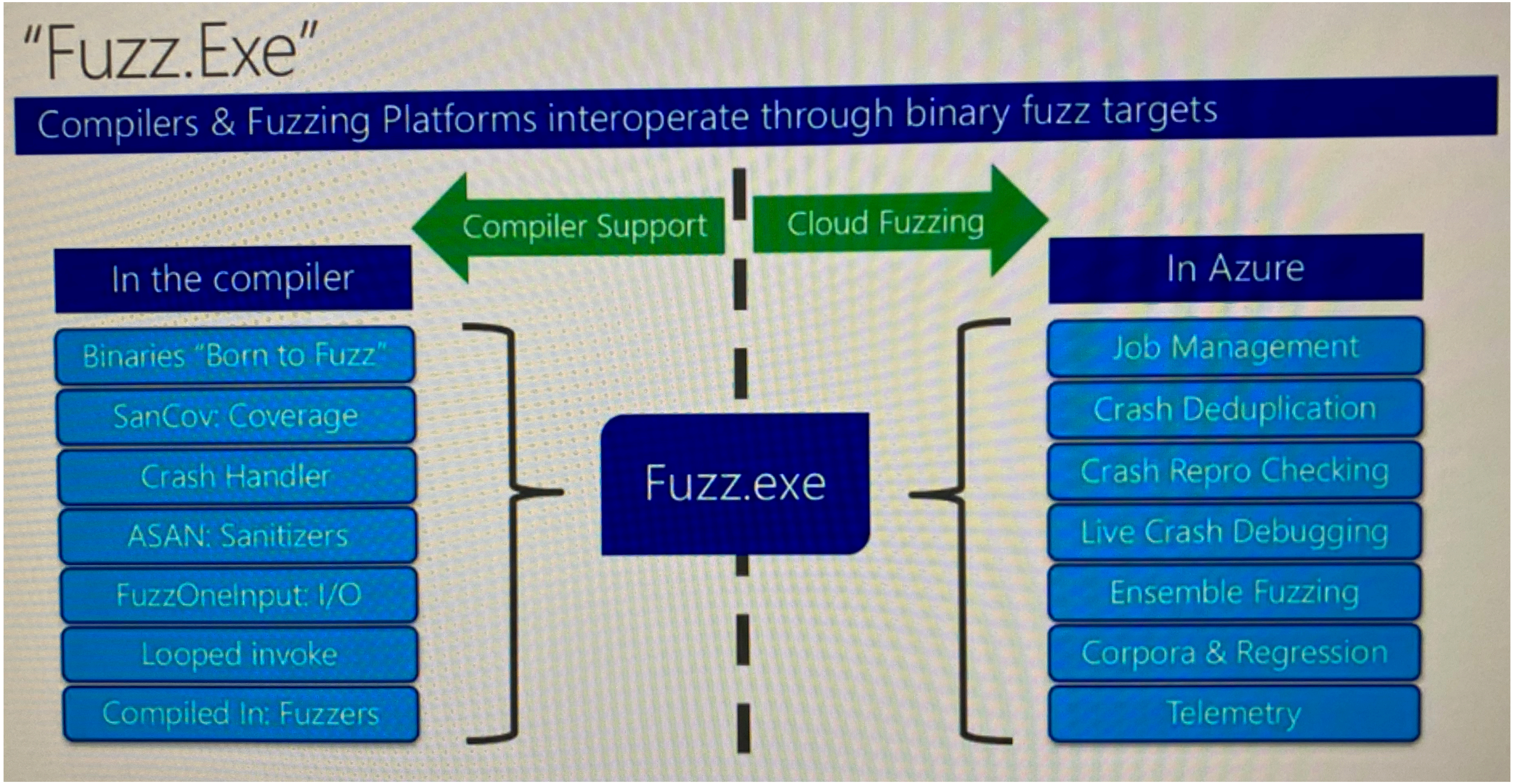
github.com/microsoft/onefuzz-samples

{ ASan + Fuzzing } => Azure



Azure MSRD service

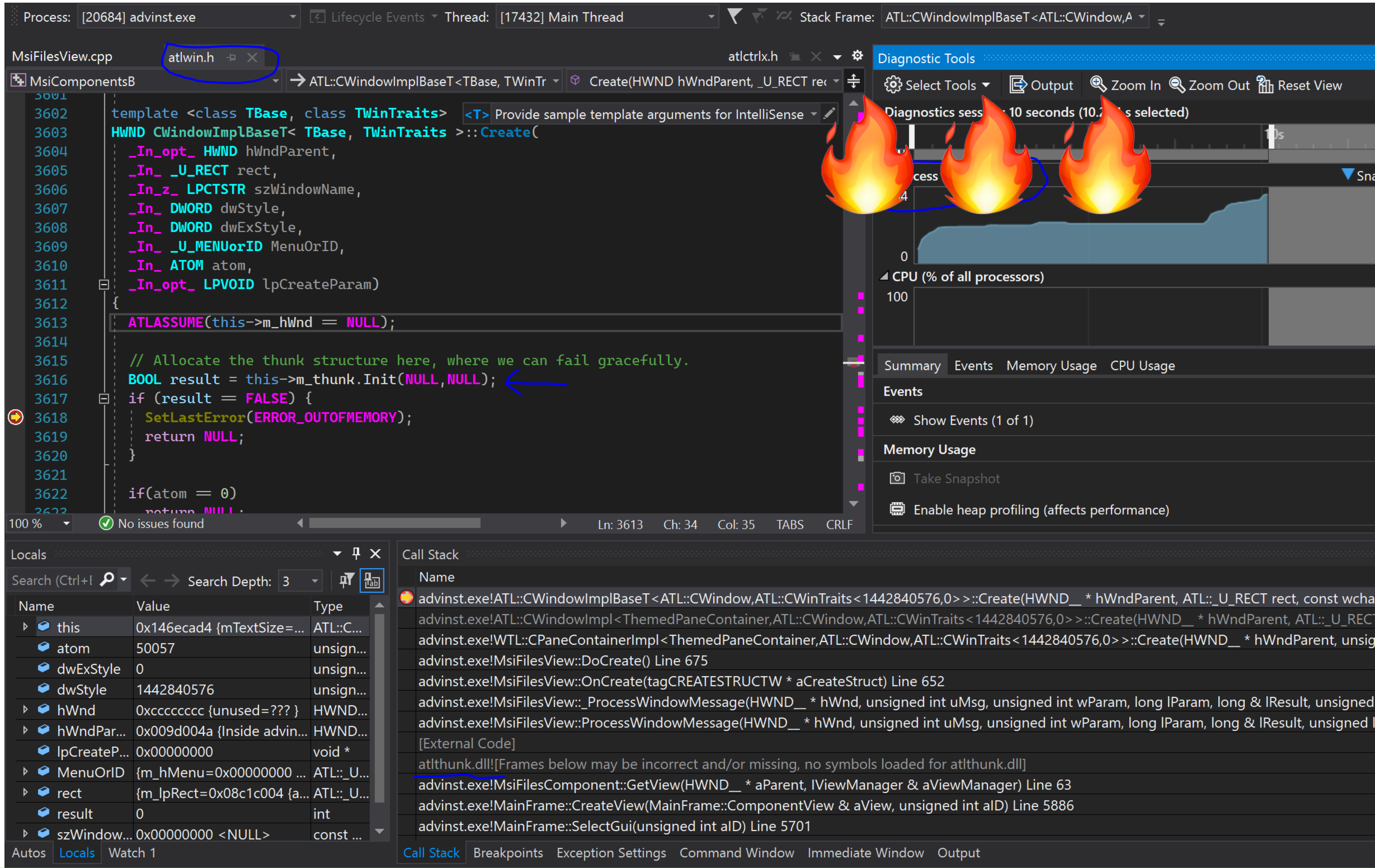
{ ASan + Fuzzing }

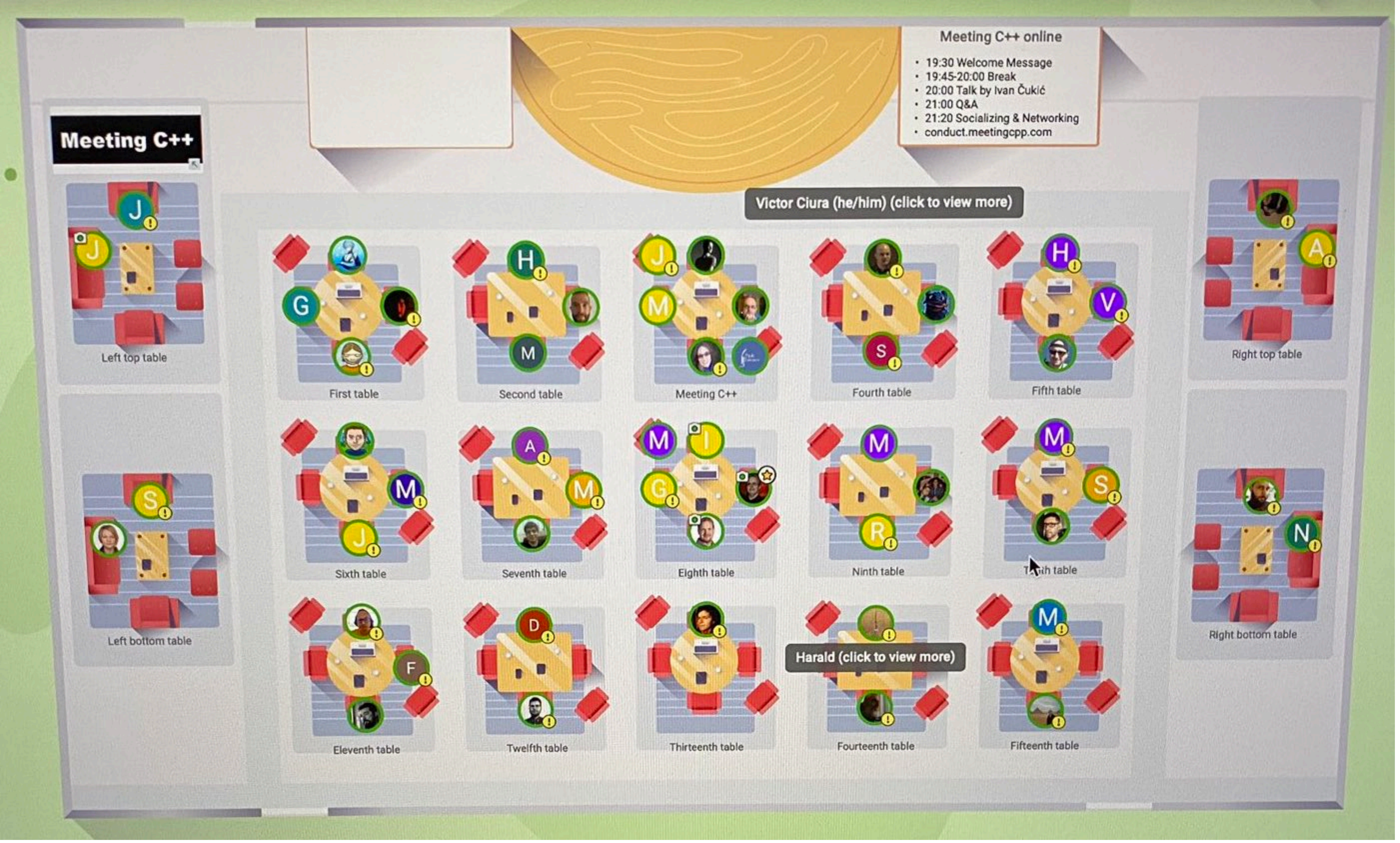


https://sched.co/e7C0

I hope you're now as excited as I am for leveraging the power of ASan on Windows

Looking forward to many days of bug-fixing ahead 😬




Meeting C++ online
19:30 Welcome Message
19:45-20:00 Break
20:00 Talk by Ivan Čukić
21:00 Q&A
21:20 Socializing & Networking
conduct.meetingcpp.com
Meeting C++
Victor Ciura (he/him) (click to view more)
Harald (click to view more)
Left top table
First table
Second table
Meeting C++
Fourth table
Fifth table
Right top table
Sixth table
Seventh table
Eighth table
Ninth table
Left bottom table
Right bottom table
Eleventh table
Twelfth table
Thirteenth table
Fourteenth table
Fifteenth table

Q & A

Meeting C++ 2020

ONLINE

September 24

2020: The Year of Sanitizers?

Victor Ciura

Principal Engineer

CAPHYON

@ciura_victor