

# Symbolism: Rainbows and Crashes

**Meeting C++ 2020**

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# Abstract

Crashed ! Now What ? “It works on my machine” :) Those little words that make the heart of QAs and clients skip a beat. Sometimes reproducing a crash on a developer's machine is next to impossible. Most of the time remote debugging is out of the question and all you're left with are some scant log files and maybe a memory dump file, if you're lucky. Wouldn't you like to know the exact point of failure in the program and how it got there, on the client's PC ?

How can you get your hands on a StackTrace of that crash on the client's machine ? And how can you make any sense of it without symbols (client deployed Release build) ?

In this session, I'll present a Windows specific technique we developed, that my team uses regularly to debug such scenarios in production. We leverage OS APIs like the Image Help Library (ImageHlp.dll), the Debug Help Library (DbgHelp.dll) to work with PE/COFF images and PDBs and reconstruct symbolicated StackTraces for Release crashes in production. The technique and APIs work all the way from Windows XP up to Windows 10, both for x86 and x64 executables.

We'll see how symbols are loaded and how PDBs work, we'll discuss partial/incremental PDBs and we'll have to get comfortable with Structured Exception Handling (SEH). Did I mention Address Space Layout Randomization (ASLR) ? This is going to be fun :)

Come with me on this journey and we'll walk the stack together, to reconstruct each frame, from a few pointers and some symbols.



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

# Q & A



# About me



**Advanced Installer**



**Clang Power Tools**



# The Quest For A Better Crash

Vignette in 3 parts

Remember the crash

Roll your own

The Future: post-pandemic crashes

# Disclaimer

**Windows\***

**x86/x64**

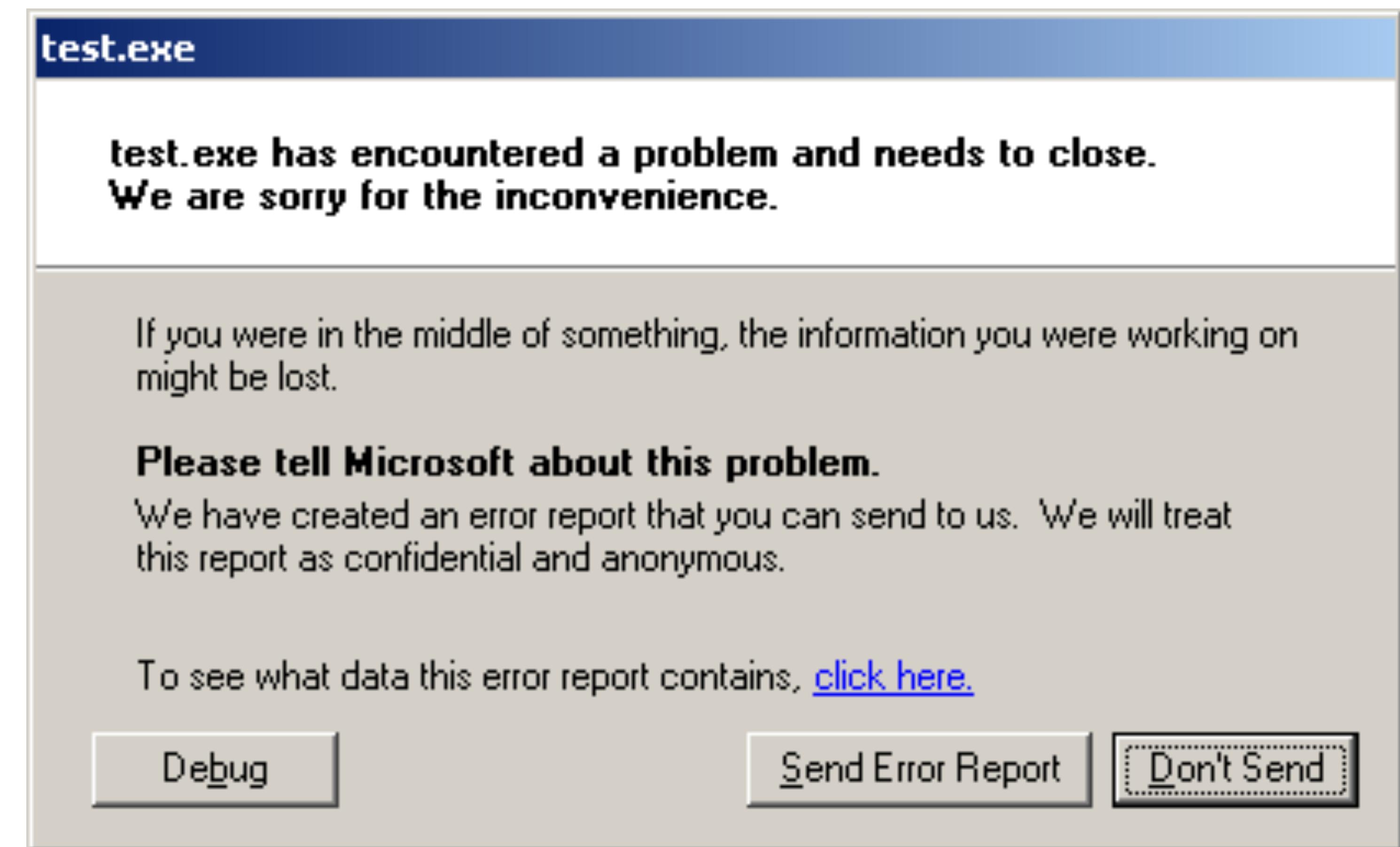
\* Mostly, with some bits about ISO C++ ([P0881](#)) at the end

## Part I

# Remember the crash

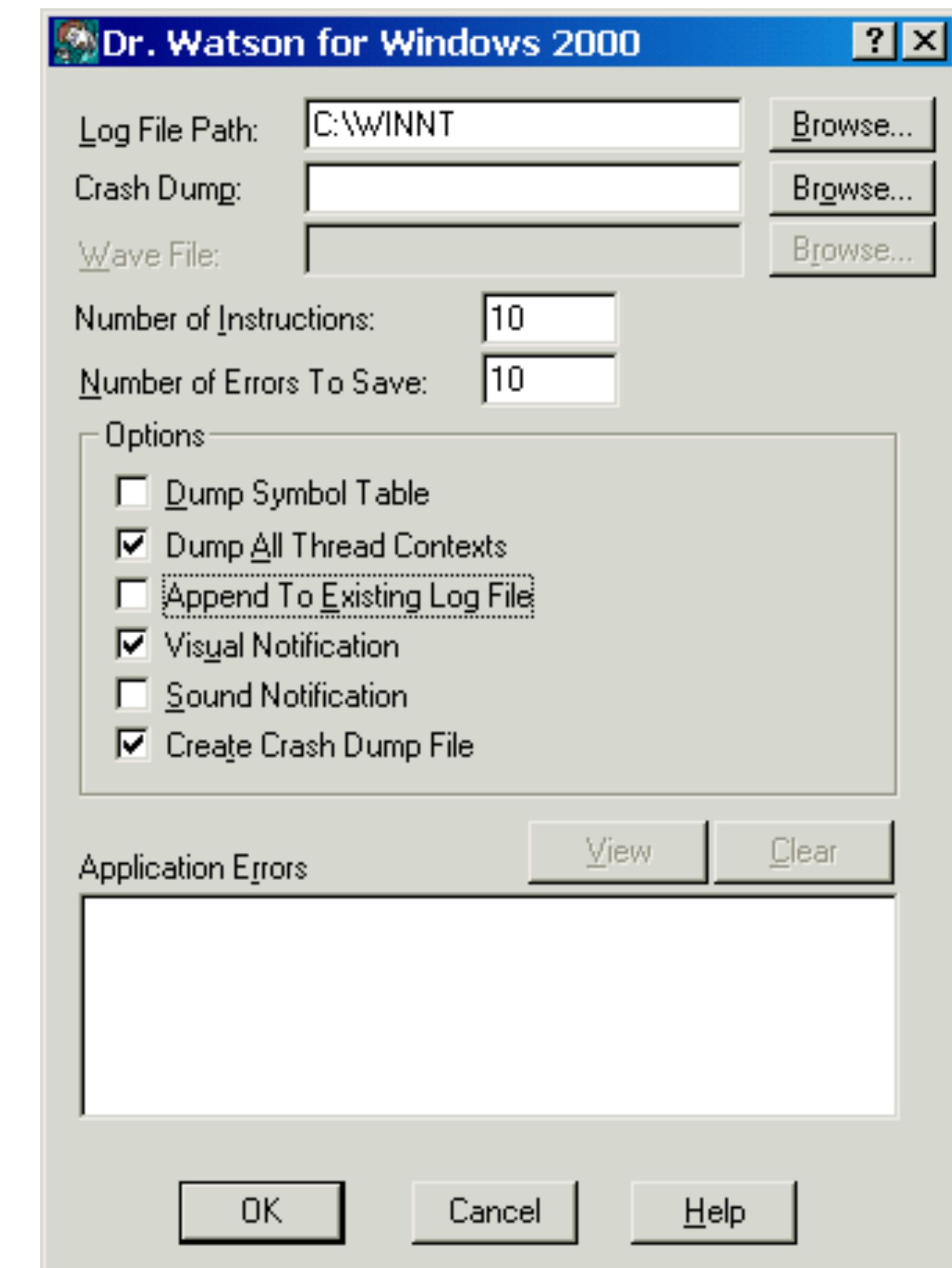
# Remember the crash

We've all been there...



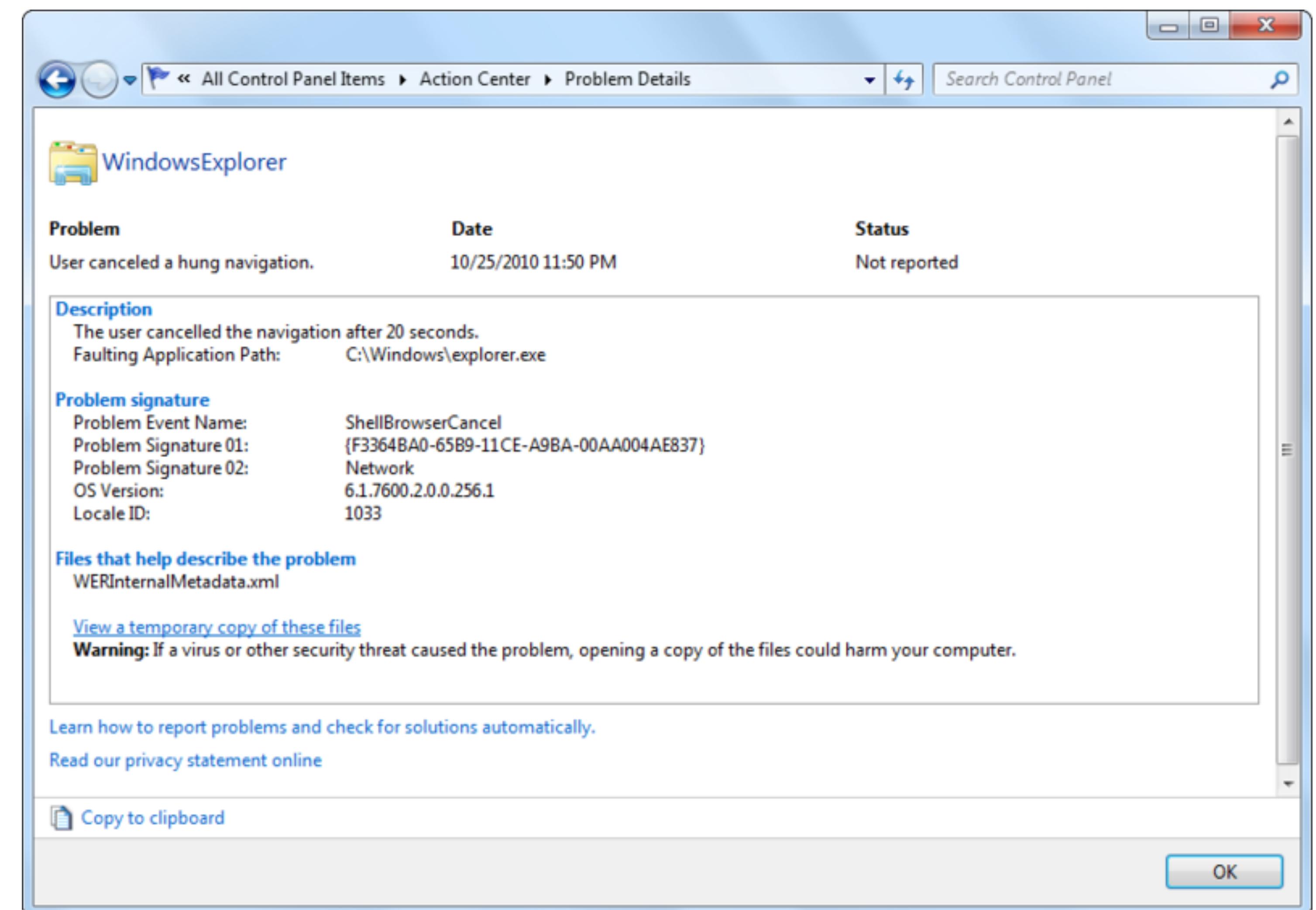
# Remember the crash

Some of us might even remember  
our old friend **Dr. Watson**



# Remember the crash

... or his modern friend,  
Windows Error Reporting



**But, where do all these crashes go?**



# Crash Paradise

Questions I had over 10 years ago,  
before any Store or Windows Dev Center

Is this even available for third-party Windows apps ?

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Is this even available for third-party Windows apps ?

How can we register to receive such crash dumps ?

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# Crash Paradise

Is this even available for third-party Windows apps ?

How can we register to receive such crash dumps ?

What does it cost ?

Questions I had over 10 years ago,  
before any Store or Windows Dev Center

# Crash Paradise

Is this even available for third-party Windows apps ?

How can we register to receive such crash dumps ?

What does it cost ?

How does the crash data look like ? Who owns it ?

Questions I had over 10 years ago,  
before any Store or Windows Dev Center

# Stack Trace

I just wanted this...

```
#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)
```

# Crash Paradise

The answers turned out to be... *complicated* :(

[docs.microsoft.com/en-us/windows/win32/debug/symbol-servers-and-symbol-stores](https://docs.microsoft.com/en-us/windows/win32/debug/symbol-servers-and-symbol-stores)

# Crash Paradise

The answers turned out to be... *complicated* :(

... custom registration for each app version,  
**Microsoft Symbol Server** instances (deployed on-premise),  
**Symbol Stores**, etc.

... a DevOps nightmare!

[docs.microsoft.com/en-us/windows/win32/debug/symbol-servers-and-symbol-stores](https://docs.microsoft.com/en-us/windows/win32/debug/symbol-servers-and-symbol-stores)

## Part II

# Roll your own

# Crash Love

Like any good programmer, I decided to build my own



# Crash Love

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Goals:

# Crash Love

Like any good programmer, I decided to build my own



Goals:

# Crash Love

Like any good programmer, I decided to build my own



Goals:

- quick to develop

Like any good programmer, I decided to build my own



## Goals:

- quick to develop
- easy to integrate into our CI/CD (no special service, symbol server)

Like any good programmer, I decided to build my own



## Goals:

- quick to develop
- easy to integrate into our CI/CD (no special service, symbol server)
- zero footprint on client side (not shipping symbols)

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## Goals:

- quick to develop
- easy to integrate into our CI/CD (no special service, symbol server)
- zero footprint on client side (not shipping symbols)
- zero perf impact on Release binaries (on the happy path)

Like any good programmer, I decided to build my own



## Goals:

- quick to develop
- easy to integrate into our CI/CD (no special service, symbol server)
- zero footprint on client side (not shipping symbols)
- zero perf impact on Release binaries (on the happy path)
- easy to use standalone tool (non-dev machine) for processing crash reports

# Workflow

# CI/CD Pipelines



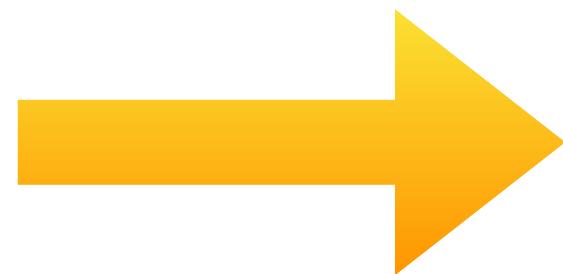
**Jenkins**



**GitLab**



**Build artifacts**



# CI/CD Artifacts

Build artifacts for git commit: [c087f2e6](#)

symbols archive 

standalone tool  
for processing  
crash reports 

Name	Date modified	Type	Size
 advinst-c087f2e6.dsym	10/22/2020 3:00 PM	DSYM File	184,323 KB
 advinst-c087f2e6.iso	10/22/2020 3:02 PM	Disc Image File	145,786 KB
 advinst-c087f2e6.iso.md5	10/22/2020 3:02 PM	MD5 File	1 KB
 advinst-c087f2e6.msi	10/22/2020 3:02 PM	Windows Installer Package	144,965 KB
 advinst-c087f2e6.msi.sha1	10/22/2020 3:02 PM	SHA1 File	1 KB
 advinst-c087f2e6.msix	10/22/2020 3:02 PM	MSIX File	152,710 KB
 advinst-c087f2e6.msix.sha1	10/22/2020 3:02 PM	SHA1 File	1 KB
 SymbolicateTool.msi	10/22/2020 3:00 PM	Windows Installer Package	1,524 KB
 symbols-c087f2e6.msi	10/22/2020 3:00 PM	Windows Installer Package	1,038 KB
 vs11_extension.vsix	10/22/2020 3:00 PM	Microsoft Visual Studio Extension	711 KB
 vs12_extension.vsix	10/22/2020 3:00 PM	Microsoft Visual Studio Extension	713 KB
 vs14_extension.vsix	10/22/2020 3:00 PM	Microsoft Visual Studio Extension	735 KB
 vs15_extension.vsix	10/22/2020 3:00 PM	Microsoft Visual Studio Extension	748 KB
 vs16_extension.vsix	10/22/2020 3:00 PM	Microsoft Visual Studio Extension	713 KB

# CI/CD Artifacts

## Symbols archive for a **Release** build

C:\Users\victo\Downloads\advinst-c087f2e6.dsym\advinst-c087f2e6\bin\x86\										
Name	Size	Packed Size	Modified	Created	Access...	Attribu...	Encryp...	Comm...	CRC	Method
..										
advinst.pdb	506 286 080	118 968 797	2020-10-22 13:46		A	-			4DE785A5	Deflate
ExternalUi.pdb	27 258 880	6 865 327	2020-10-22 13:47		A	-			2D5D16DC	Deflate
Repackager.pdb	74 829 824	16 813 693	2020-10-22 13:50		A	-			8891255E	Deflate
VmLauncher.pdb	45 469 696	10 516 761	2020-10-22 13:53		A	-			09A02E1B	Deflate

[advinst-c087f2e6.dsym](#) - basically, a ZIP bundle

# Symbols



PDB == 42

Use **/DEBUG:FULL** for Release builds & archiving symbols

The screenshot shows the 'Configuration Properties' section of the Visual Studio Properties Manager. Under the 'Linker' category, the 'Debugging' option is selected. A context menu is open over the 'Generate Debug Info' dropdown, listing several options:

- Generate Debug Info (selected)
- Generate Program Database File
- Strip Private Symbols
- Generate Map File
- Map File Name
- Map Exports
- Debuggable Assembly

The 'Generate Debug Info' option is highlighted with a blue selection bar, and its tooltip indicates it generates debug information optimized for sharing and publishing (/**DEBUG:FULL**). The other options listed are: No (/**DEBUG**), Generate Debug Information optimized for faster links (/**DEBUG:FASTLINK**), and another entry for Generate Debug Information optimized for sharing and publishing (/**DEBUG:FULL**).

[docs.microsoft.com/en-us/cpp/build/reference/debug-generate-debug-info](https://docs.microsoft.com/en-us/cpp/build/reference/debug-generate-debug-info)

# No Symbols

## You don't want to see a dry stack trace (crash report)

```
[SEH_AV_WRITE_NULLPTR] ACCESS_VIOLATION (0xc0000005) at address [0x000000014002772f]

Advanced Repackager (x64) 12.8 build 69285
*** Stack Trace (x64) ***

[0x000000014002772f] -----
[0x000000014002911c] -----
[0x0000000140028f66] -----
[0x0000000140026f86] -----
[0x0000000140026e68] -----
[0x0000000140020be8] -----
[0x0000000076b979b7] CreateDialogParamW()
[0x0000000076b97792] CreateDialogParamW()
[0x0000000076b976c2] CreateDialogParamW()
[0x0000000076b89bd1] TranslateMessageEx()
[0x0000000076b86aa8] SetTimer()
[0x0000000076b86bad] SendMessageW()
[0x000007fefc0092a0] Ordinal342()
[0x000007fefc008604] Ordinal342()
[0x000007fefc0217bd] -----
[0x000007fefc023075] -----
[0x000007fefc023223] -----
[0x000007fefc024491] -----
[0x0000000076b979b7] -----
[0x0000000076b97792] -----
[0x0000000076b976c2] -----
[0x0000000076b89bd1] TranslateMessageEx()
[0x0000000076b83bfc] CallWindowProcW()
[0x0000000076b83b78] CallWindowProcW()
[0x000000014003268e] -----
[0x0000000140031f33] -----
[0x0000000140032257] -----
[0x00000001400312d4] -----
```

# Stack Trace Symbols



**Victor Zverovich (vaut)**  
@vzverovich



When someone asks if a stack trace  
looks familiar...



# Context

TFW you've got a fresh repro case  
and you can dive into a debugging  
session...

The screenshot shows a debugger interface with the following details:

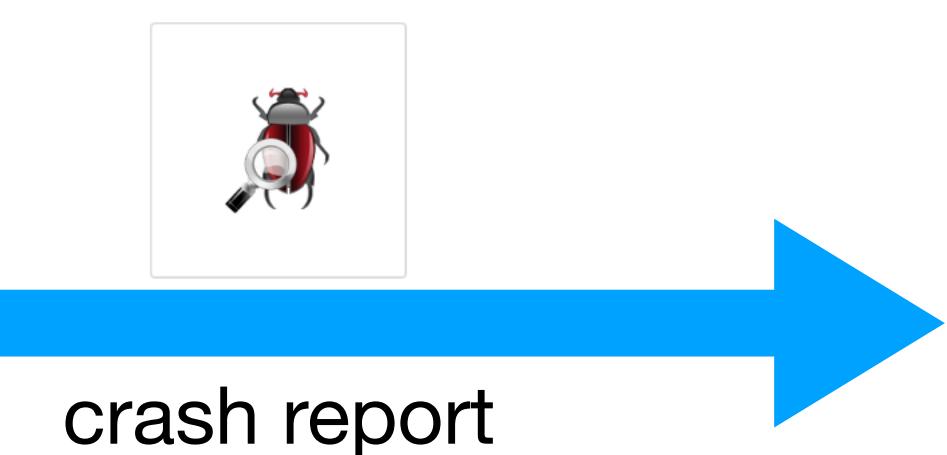
- Code View:** The main window displays the `MsiFilesView.cpp` file. A specific line of code is highlighted:

```
3616     BOOL result = this->m_thunk.Init(NULL,NULL); ←
```
- Locals View:** Shows local variables and their values.
- Call Stack View:** Displays the call stack of functions.
- Diagnostic Tools View:** Shows memory usage over time, with a blue box highlighting the "Process Memory (MB)" section.

# Sometimes you crash

The screenshot shows the Advanced Installer 17.8 application window. The menu bar includes File, Home, View, Settings, Wizards, and various build/run options. The left sidebar contains sections for Product Information (Product Details, Digital Signature, Updater, Upgrades, Licensing, CD/DVD Autorun, Multiple Instances), Resources (Files and Folders, Tiles, Java Products, Registry, File Associations, Assemblies, Drivers, Services), and a Project section with a Find bar and simple view toggle.

In the center, the "Digital Signature" tab is selected. It shows settings for enabling signing, using a built-in sign tool, and selecting a Software Publisher Certificate from the certificate store. A modal dialog box is displayed, stating: "The application ran into a problem that it couldn't handle. Sorry for the inconvenience." It has "Details >>" and "Send Error Report" buttons. Below the dialog, there are three fire emoji (🔥🔥🔥) and a patching section with a checkbox for installing patches without elevation.



## Support service

- collect
- symbolicate
- triage

# Symbolicate Tool

Symbolicate Tool (x64)

Extract Symbol Package

MSI Package: C:\Users\Victor\Downloads\advinst17.6\advinst-c087f2e6.msi

Loaded Symbols: bin\x64\Repackager

Debuggee

EXE File: C:\Users\Victor\AppData\Local\Temp\Symbol Packages\advinst-c087f2e6\bin\x64\Repackager.exe

PDB File: C:\Users\Victor\AppData\Local\Temp\Symbol Packages\advinst-c087f2e6\bin\x64\Repackager.pdb

Command Line:

Stack Trace

Dump File: C:\Users\Victor\Downloads\Crash Report.st

[SEH\_AV\_WRITE\_NULLPTR] ACCESS\_VIOLATION (0xc0000005) at address [0x000000014002772f]

Advanced Repackager (x64) 17.6 build c087f2e6  
\*\*\* Stack Trace (x64) \*\*\*

```
[0x000000014002772f] ProductDetailsPage::OnWizardNext() -> productdetailspage.cpp:97
[0x000000014002911c] WTL::CPropertyPageImpl<ProductDetailsPage,WTL::CPropertyPageWindow>::OnCreate()
[0x0000000140028f66] CResizablePropertyPageImpl<ProductDetailsPage,WTL::CPropertyPageWindow>::OnInitialUpdate()
[0x0000000140026f86] ProductDetailsPage::_ProcessWindowMessage() -> productdetailspage.cpp:97
[0x0000000140026e68] ProductDetailsPage::ProcessWindowMessage() -> productdetailspage.cpp:97
[0x0000000140020be8] ATL::CDialogImplBaseT<WTL::CPropertyPageWindow>::DialogProc() -> dialogbase.cpp:100
[0x0000000076b979b7] CreateDialogParamW()
[0x0000000076b97792] CreateDialogParamW()
[0x0000000076b976c2] CreateDialogParamW()
[0x0000000076b89bd1] TranslateMessageEx()
[0x0000000076b86aa8] SetTimer()
[0x0000000076b86bad] SendMessageW()
[0x0000007fefc0092a0] Ordinal342()
[0x0000007fefc008604] Ordinal342()
[0x0000007fefc0217bd] CreatePropertySheetPage()
```

Symbolicate !



# Symbolicate Tool

Symbolicate Tool (x64)

Extract Symbol Package

MSI Package: C:\Users\victo\Downloads\advinst17.6\advinst-c087f2e6.msi

Loaded Symbols: bin\x64\Repackager

Debuggee

EXE File: C:\Users\victo\AppData\Local\Temp\Symbol Packages\advinst-c087f2e6\bin\x64\Repackager.exe

PDB File: C:\Users\victo\AppData\Local\Temp\Symbol Packages\advinst-c087f2e6\bin\x64\Repackager.pdb

Command Line:

Stack Trace

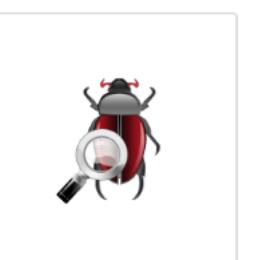
Dump File: C:\Users\victo\Downloads\Crash Report.st

```
[SEH_AV_WRITE_NULLPTR] ACCESS_VIOLATION (0xc0000005) at address [0x000000014002772f]
Advanced Repackager (x64) 17.6 build c087f2e6
*** Stack Trace (x64) ***

[0x000000014002772f] ProductDetailsPage::OnWizardNext() -> productdetailspage.cpp:97
[0x000000014002911c] WTL::CPropertyPageImpl<ProductDetailsPage,WTL::CPropertyPageWindow>::OnCreate()
[0x0000000140028f66] CResizablePropertyPageImpl<ProductDetailsPage,WTL::CPropertyPageWindow>::OnInitialUpdate()
[0x0000000140026f86] ProductDetailsPage::_ProcessWindowMessage() -> productdetailspage.cpp:97
[0x0000000140026e68] ProductDetailsPage::ProcessWindowMessage() -> productdetailspage.cpp:97
[0x0000000140020be8] ATL::CDialogImplBaseT<WTL::CPropertyPageWindow>::DialogProc() -> dialogproc.cpp:100
[0x0000000076b979b7] CreateDialogParamW()
[0x0000000076b97792] CreateDialogParamW()
[0x0000000076b976c2] CreateDialogParamW()
[0x0000000076b89bd1] TranslateMessageEx()
[0x0000000076b86aa8] SetTimer()
[0x0000000076b86bad] SendMessageW()
[0x0000007fefc0092a0] Ordinal342()
[0x0000007fefc008604] Ordinal342()
[0x0000007fefc0217bd] CreatePropertySheetPage()
```

Symbolicate !

← select build



# Symbolicate Tool

Symbolicate Tool (x64)

Extract Symbol Package

MSI Package: C:\Users\victo\Downloads\advinst17.6\advinst-c087f2e6.msi

Loaded Symbols: bin\x64\Repackager

Debuggee

EXE File: C:\Users\victo\AppData\Local\Temp\Symbol Packages\advinst-c087f2e6\bin\x64\Repackager.exe

PDB File: C:\Users\victo\AppData\Local\Temp\Symbol Packages\advinst-c087f2e6\bin\x64\Repackager.pdb

Command Line:

Stack Trace

Dump File: C:\Users\victo\Downloads\Crash Report.st

```
[SEH_AV_WRITE_NULLPTR] ACCESS_VIOLATION (0xc0000005) at address [0x000000014002772f]
Advanced Repackager (x64) 17.6 build c087f2e6
*** Stack Trace (x64) ***

[0x000000014002772f] ProductDetailsPage::OnWizardNext() -> productdetailspage.cpp:97
[0x000000014002911c] WTL::CPropertyPageImpl<ProductDetailsPage,WTL::CPropertyPageWindow>::OnCreate()
[0x0000000140028f66] CResizablePropertyPageImpl<ProductDetailsPage,WTL::CPropertyPageWindow>::OnInitialUpdate()
[0x0000000140026f86] ProductDetailsPage::_ProcessWindowMessage() -> productdetailspage.cpp:97
[0x0000000140026e68] ProductDetailsPage::ProcessWindowMessage() -> productdetailspage.cpp:97
[0x0000000140020be8] ATL::CDialogImplBaseT<WTL::CPropertyPageWindow>::DialogProc() -> dialogproc.cpp:100
[0x0000000076b979b7] CreateDialogParamW()
[0x0000000076b97792] CreateDialogParamW()
[0x0000000076b976c2] CreateDialogParamW()
[0x0000000076b89bd1] TranslateMessageEx()
[0x0000000076b86aa8] SetTimer()
[0x0000000076b86bad] SendMessageW()
[0x0000007fefc0092a0] Ordinal342()
[0x0000007fefc008604] Ordinal342()
[0x0000007fefc0217bd] CreatePropertySheetPage()
```

Symbolicate !

← select build

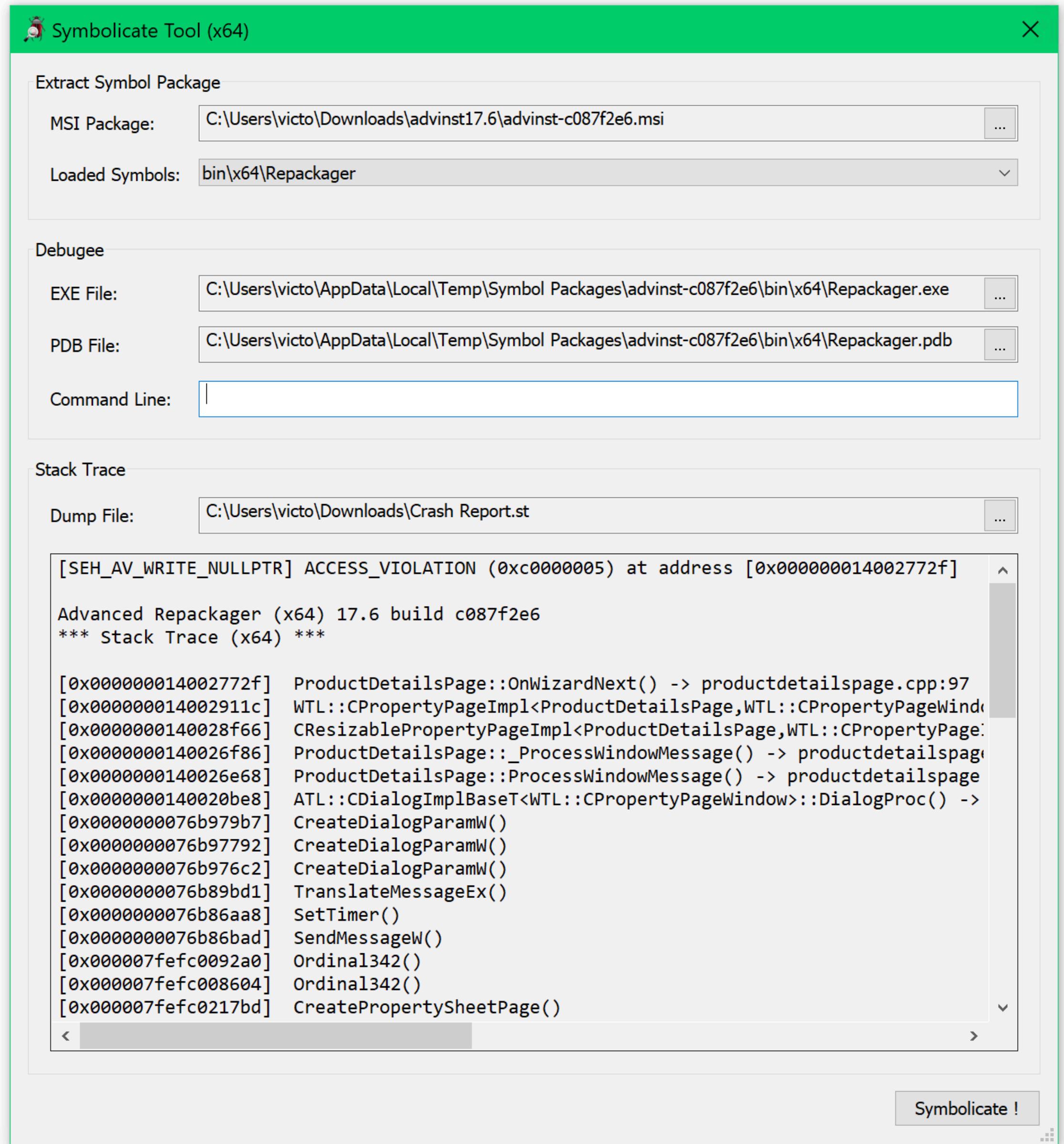


Build artifacts



advinst-c087f2e6.dsym

# Symbolicate Tool



← select build



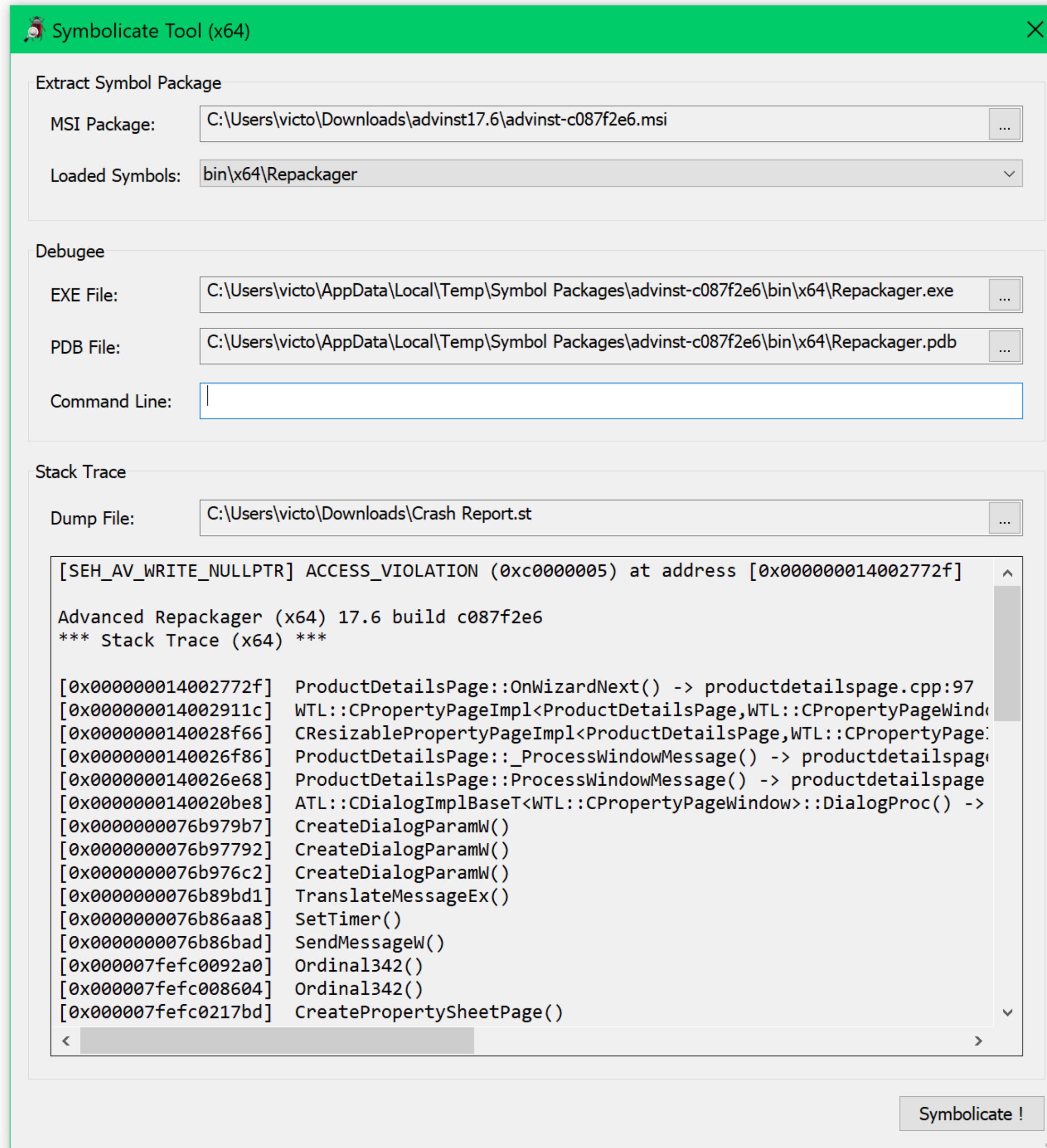
Build artifacts

advinst-c087f2e6.dsym

← select crash report



# Symbolicate Tool



← select build



Build artifacts

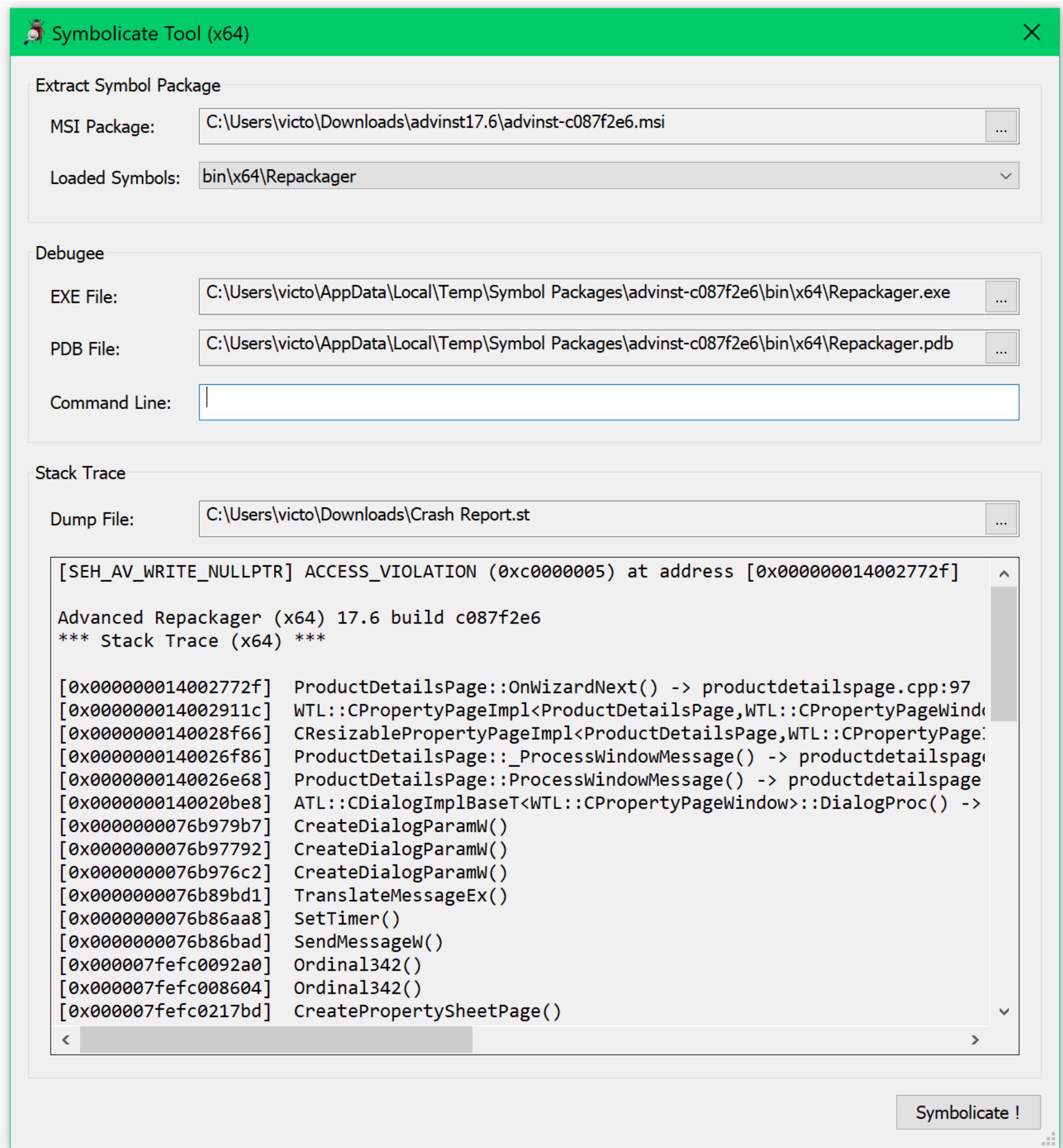
advinst-c087f2e6.dsym

← select crash report



← get a full stack trace

# Symbolicate Tool



← select build



Build artifacts

advinst-c087f2e6.dsym

← select crash report



← get a full stack trace

Fix bug & rejoice!

# Symbols

[SEH\_AV\_WRITE\_NULLPTR] ACCESS\_VIOLATION (0xc0000005) at address [0x000000014002772f]

Advanced Repackager (x64) 17.6 build c087f2e6

\*\*\* Stack Trace (x64) \*\*\*

```
[0x000000014002772f] ProductDetailsPage::OnWizardNext() -> productdetailspage.cpp:97
[0x000000014002911c] WTL::CPropertyPageImpl<ProductDetailsPage,WTL::CPropertyPageWindow>::OnNotify() -> atlDlg.h:4527
[0x0000000140028f66] CResizablePropertyPageImpl<ProductDetailsPage>::_ProcessWindowMessage() -> resizablepropsheetimpl.h:443
[0x0000000140026f86] ProductDetailsPage::_ProcessWindowMessage() -> productdetailspage.h:36
[0x0000000140026e68] ProductDetailsPage::ProcessWindowMessage() -> productdetailspage.h:31
[0x0000000140020be8] ATL::CDialogImplBaseT<WTL::CPropertyPageWindow>::DialogProc() -> atlwin.h:3862
[0x0000000076b979b7] CreateDialogParamW()
[0x0000000076b97792] CreateDialogParamW()
[0x0000000076b976c2] CreateDialogParamW()
[0x0000000076b89bd1] TranslateMessageEx()
[0x0000000076b86aa8] SetTimer()
[0x0000000076b86bad] SendMessageW()
[0x000007fefc0092a0] Ordinal342()
[0x000007fefc008604] Ordinal342()
[0x000007fefc0217bd] CreatePropertySheetPage()
[0x000007fefc023075] CreatePropertySheetPage()
[0x000007fefc023223] CreatePropertySheetPage()
[0x000007fefc024491] CreatePropertySheetPage()
[0x0000000076b979b7] CreateDialogParamW()
[0x0000000076b97792] CreateDialogParamW()
[0x0000000076b976c2] CreateDialogParamW()
[0x0000000076b89bd1] TranslateMessageEx()
[0x0000000076b83bfc] CallWindowProcW()
[0x0000000076b83b78] CallWindowProcW()
[0x000000014003268e] WTL::CPropertySheetImpl<RepackagerWizard,WTL::CWizard97SheetWindow>::OnCommand() -> atlDlg.h:4257
[0x0000000140031f33] WTL::CWizard97SheetImpl<RepackagerWizard,WTL::CWizard97SheetWindow>::ProcessWindowMessage() -> atlDlg.h:5387
[0x0000000140032257] CResizablePropSheetImpl<RepackagerWizard>::_ProcessWindowMessage() -> resizablepropsheetimpl.h:138
[0x00000001400312d4] RepackagerWizard::ProcessWindowMessage() -> repackagerwizard.h:48
[0x00000001400338a3] ATL::CWindowImplBaseT<WTL::CWizard97SheetWindow,ATL::CWinTraits<1442840576,0>>::WindowProc() -> atlwin.h:3508
[0x0000000076b89bd1] TranslateMessageEx()
[0x0000000076b86aa8] SetTimer()
[0x0000000076b86bad] SendMessageW()
```

# Our first clues...

[SEH\_AV\_WRITE\_NULLPTR] ACCESS\_VIOLATION (0xc0000005) at address [0x000000014002772f]

Advanced Repackager (x64) 17.6 build c087f2e6

\*\*\* Stack Trace (x64) \*\*\*

[0x000000014002772f] **ProductDetailsPage::OnWizardNext() -> productdetailspage.cpp:97**  
[0x000000014002911c] WTL::CPropertyPageImpl<ProductDetailsPage>::OnNotify() -> atlDlg.h:4527  
[0x0000000140026f86] ProductDetailsPage::\_ProcessWindowMessage() -> productdetailspage.h:36  
[0x0000000140026e68] ProductDetailsPage::ProcessWindowMessage() -> productdetailspage.h:31  
[0x0000000140020be8] ATL::CDialogImplBaseT<WTL::CPropertyPageWindow>::DialogProc() -> atlwin.h:3862

...

[0x000000014003268e] WTL::CPropertySheetImpl<RepackagerWizard>::OnCommand() -> atlDlg.h:4257  
[0x00000001400312d4] RepackagerWizard::ProcessWindowMessage() -> repackagerwizard.h:48  
[0x00000001400338a3] ATL::CWindowImplBaseT<WTL::CWizard97SheetWindow>::WindowProc() -> atlwin.h:3508  
[0x000000014004176e] Repackager::RunNormal() -> repackager.cpp:192  
[0x00000001400429bb] wWinMain() -> repackager.cpp:250  
[0x0000000140089d02] \_\_tmainCRTStartup() -> crtexe.c:547  
[0x0000000076a6652d] BaseThreadInitThunk()  
[0x000000007715c521] RtlUserThreadStart()  
[0x0000000000a00000] MODULE\_BASE\_ADDRESS

# **How it works**

## Structured Exception Handling (SEH)

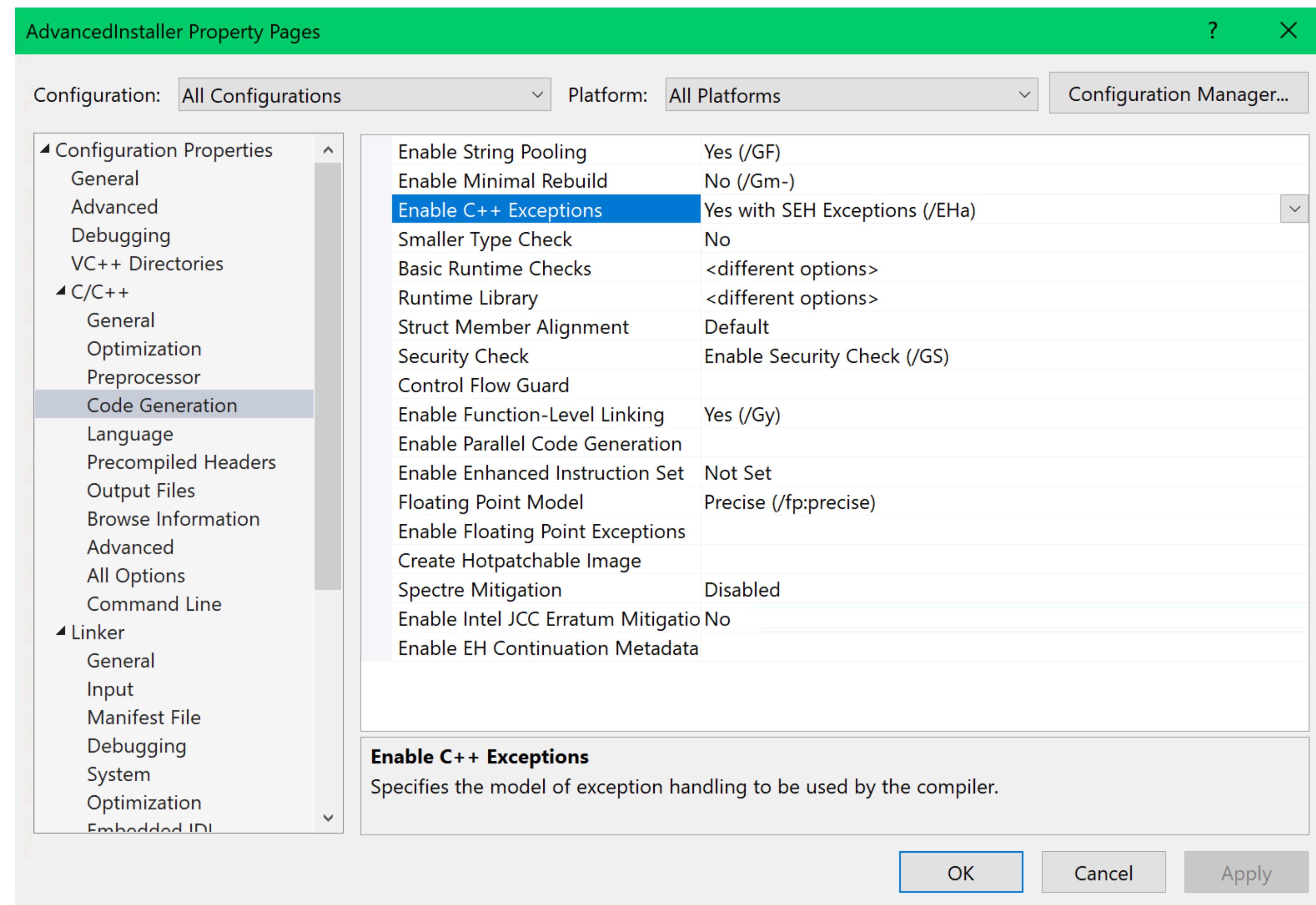
/EH<sub>a</sub>

we use async exceptions on all modules

[docs.microsoft.com/en-us/windows/win32/debug/structured-exception-handling](https://docs.microsoft.com/en-us/windows/win32/debug/structured-exception-handling)

[docs.microsoft.com/en-us/cpp/cpp/structured-exception-handling-c-cpp?view=msvc-160](https://docs.microsoft.com/en-us/cpp/cpp/structured-exception-handling-c-cpp?view=msvc-160)

## Structured Exception Handling (SEH)



## Structured Exception Handling (SEH)

```
<ItemDefinitionGroup>
  <ClCompile>
    <DebugInformationFormat>ProgramDatabase</DebugInformationFormat>
    <ExceptionHandling>Async</ExceptionHandling>
  </ClCompile>
  <Link>
    <GenerateDebugInformation>DebugFull</GenerateDebugInformation>
    <SubSystem>Windows</SubSystem>
  </Link>
</ItemDefinitionGroup>
```

**/EHs /DEBUG:FULL /Zi**

# Structured Exception Handling (SEH)

Handle C structured exceptions (Win32) as C++ typed exceptions:

```
_set_se_translator(ExceptionHandling::TransFunc);
```

[docs.microsoft.com/en-us/cpp/c-runtime-library/reference/set-se-translator](https://docs.microsoft.com/en-us/cpp/c-runtime-library/reference/set-se-translator)

# Unhandled Exceptions

```
static bool installedFilter = false;  
if (!installedFilter)  
{  
    ::SetUnhandledExceptionFilter(ExceptionHandling::UnhandledException);  
    installedFilter = true;  
}
```

If an exception occurs in a process that is not being debugged,  
and the exception makes it to the **Unhandled** exception filter => [we intercept it](#)

This replaces the existing top-level exception filter for ALL existing and  
ALL future threads in the calling process.

# Unhandled Exceptions

```
LONG ExceptionHandling::UnhandledException(EXCEPTION_POINTERS * aExceptionInfo)
{
    wstring message(L"[EXCEPTION_UNHANDLED] ");

    wchar_t buf[MSG_BUFFER_LEN];
    swprintf_s(buf, MSG_BUFFER_LEN, L"(0x%.8x) at address " ADDRESS_FORMAT SW_EOL,
               aExceptionInfo->ExceptionRecord->ExceptionCode,
               aExceptionInfo->ExceptionRecord->ExceptionAddress);
    message += buf;

    StackWalker::TraceFromContext(message, aExceptionInfo->ContextRecord);

    ErrMsgPresenter::Message(message);

    return EXCEPTION_EXECUTE_HANDLER;
}
```

# SEH Translator

```
void ExceptionHandling::TransFunc(unsigned int aSECode, EXCEPTION_POINTERS * aExInfo)
{
    // write the exception prolog (type, code, address, etc.)

    switch (aSECode) // decode SEH exception type
    {
        case EXCEPTION_ACCESS_VIOLATION:
            swprintf_s(buf, MSG_BUFFER_LEN, L"%hs (0x%.8x) at address " ADDRESS_FORMAT SW_EOL,
                       "ACCESS_VIOLATION", EXCEPTION_ACCESS_VIOLATION,
                       aExInfo->ExceptionRecord->ExceptionAddress);
            break;
        case EXCEPTION_DATATYPE_MISALIGNMENT:
            break;
        case EXCEPTION_INT_DIVIDE_BY_ZERO:
            break;
        case EXCEPTION_INT_OVERFLOW:
            break;
        case EXCEPTION_ILLEGAL_INSTRUCTION:
            break;
        case EXCEPTION_STACK_OVERFLOW:
            break;
        ...
    }
}
```

[docs.microsoft.com/en-us/windows/win32/api/winnt/ns-winnt-exception\\_record](https://docs.microsoft.com/en-us/windows/win32/api/winnt/ns-winnt-exception_record)

# SEH Translator

```
void ExceptionHandling::TransFunc(unsigned int aSECode, EXCEPTION_POINTERS * aExInfo)
{
    ...
    SehException::SETYPE seType = SehException::SEH_GENERIC;

    // for AV exception, we can determine the type of operation that caused it
    if (aSECode == EXCEPTION_ACCESS_VIOLATION)
    {
        // the first element of the array contains a read-write flag
        // that indicates the type of operation that caused the access violation
        ULONG_PTR operationType = aExInfo->ExceptionRecord->ExceptionInformation[0];

        // the second array element specifies the virtual address of the inaccessible data
        ULONG_PTR virtualAddress = aExInfo->ExceptionRecord->ExceptionInformation[1];

        if (operationType == 0)
            seType = virtualAddress ? SehException::SEH_AV_READ_BADPTR : SehException::SEH_AV_READ_NULLPTR;
        else if (operationType == 1)
            seType = virtualAddress ? SehException::SEH_AV_WRITE_BADPTR : SehException::SEH_AV_WRITE_NULLPTR;
        else if (operationType == 8)
            seType = virtualAddress ? SehException::SEH_AV_DEP_BADPTR : SehException::SEH_AV_DEP_NULLPTR;
    }

    // record SEH type info in exception message
    exceptionMsg.insert(0, L"[" + SehException::SeTypeToString(seType) + L"] ");
}
```

# SEH Translator

```
void ExceptionHandling::TransFunc(unsigned int aSECode, EXCEPTION_POINTERS * aExInfo)
{
    // write the exception prolog (type, code, address, etc.)
    // decode SEH exception type
    ...

    // walk the function call stack and gather information about each frame
    StackWalker::TraceFromContext(exceptionMsg, aExInfo->ContextRecord);

    // for AV exception, we can determine the type of operation that caused it
    ... => seType

    // extract SEH exception origin from StackTrace
    SymbolUtil::SrcPos exOrigin = GetExceptionOrigin(aExInfo->ContextRecord);

    // throw a C++ typed exception with the necessary fault information (attached)
    throw SehException(exOrigin.mFile, exOrigin.mLine, seType, exceptionMsg);
}
```

So we end up with a regular C++ exception wrapping the **SEH** info

# What's the catch ?

What about an exception **in flight** ?

Get the stack trace for the raised exception on the *current thread*.

# What's the catch ?

What about an exception **in flight** ?

Get the stack trace for the raised exception on the *current thread*.

```
wstring ExceptionHandling::GetStackTraceForCurrentException()
{
    wstring stackTrace;
    StackWalker::TraceFromContext(stackTrace, ExceptionHandling::GetCurrentExceptionContext());

    return stackTrace;
}
```

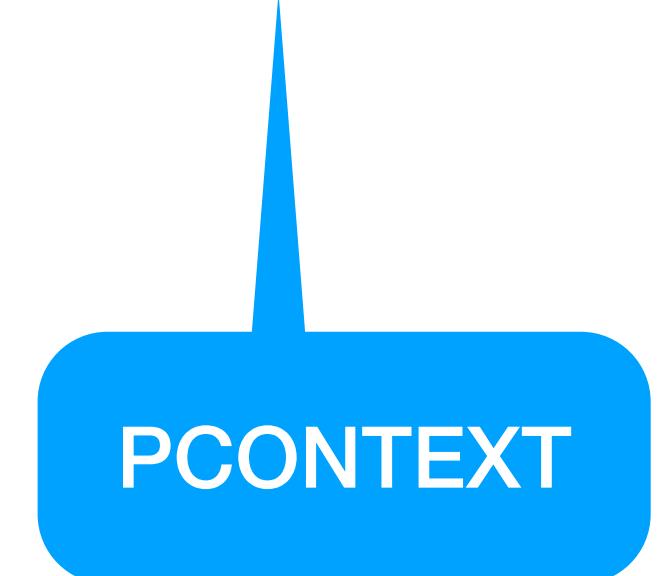
# What's the catch ?

What about an exception **in flight** ?

Get the stack trace for the raised exception on the *current thread*.

```
wstring ExceptionHandling::GetStackTraceForCurrentException()
{
    wstring stackTrace;
    StackWalker::TraceFromContext(stackTrace, ExceptionHandling::GetCurrentExceptionContext());

    return stackTrace;
}
```



PCONTEXT

# PCONTEXT

```
typedef struct _CONTEXT {
    DWORD ContextFlags;

    // This section is specified/returned if CONTEXT_DEBUG_REGISTERS is
    // set in ContextFlags. Note that CONTEXT_DEBUG_REGISTERS is NOT
    // included in CONTEXT_FULL.
    DWORD Dr0;
    DWORD Dr1;
    DWORD Dr2;
    DWORD Dr3;
    DWORD Dr6;
    DWORD Dr7;

    // This section is specified/returned if the
    // ContextFlags word contains the flag CONTEXT_FLOATING_POINT.
    FLOATING_SAVE_AREA FloatSave;

    // This section is specified/returned if the
    // ContextFlags word contains the flag CONTEXT_SEGMENTS.
    DWORD SegGs;
    DWORD SegFs;
    DWORD SegEs;
    DWORD SegDs;

    // This section is specified/returned if the
    // ContextFlags word contains the flag CONTEXT_INTEGER.
    DWORD Edi;
    DWORD Esi;
    DWORD Ebx;
    DWORD Edx;
    DWORD ECx;
    DWORD Eax;

    // This section is specified/returned if the
    // ContextFlags word contains the flag CONTEXT_CONTROL.
    DWORD Ebp;
    DWORD Eip;
    DWORD SegCs;           // MUST BE SANITIZED
    DWORD EFlags;          // MUST BE SANITIZED
    DWORD Esp;
    DWORD SegSs;

    // This section is specified/returned if the ContextFlags word
    // contains the flag CONTEXT_EXTENDED_REGISTERS.
    // The format and contexts are processor specific
    BYTE ExtendedRegisters[MAXIMUM_SUPPORTED_EXTENSION];
}
```

Contains processor-specific **register** data.

The system uses **CONTEXT** structures to perform various internal operations.

[docs.microsoft.com/en-us/windows/win32/api/winnt/ns-winnt-context](https://docs.microsoft.com/en-us/windows/win32/api/winnt/ns-winnt-context)

# EXCEPTION\_POINTERS >> PCONTEXT

We've already seen this (PCONTEXT)

```
void ExceptionHandling::TransFunc(unsigned int aSECode, EXCEPTION_POINTERS * aExInfo)
{
    StackWalker::TraceFromContext(exceptionMsg, aExInfo->ContextRecord);
    ...
}
```

```
typedef struct _EXCEPTION_POINTERS
{
    PEXCEPTION_RECORD ExceptionRecord;
    PCONTEXT ContextRecord;
} EXCEPTION_POINTERS, *PEXCEPTION_POINTERS;
```

[docs.microsoft.com/en-us/windows/win32/api/winnt/ns-winnt-exception\\_pointers](https://docs.microsoft.com/en-us/windows/win32/api/winnt/ns-winnt-exception_pointers)

# EXCEPTION\_RECORD

```
typedef struct _EXCEPTION_RECORD
{
    DWORD ExceptionCode;
    DWORD ExceptionFlags;
    struct _EXCEPTION_RECORD * ExceptionRecord;
    PVOID ExceptionAddress;
    DWORD NumberParameters;
    ULONG_PTR ExceptionInformation[EXCEPTION_MAXIMUM_PARAMETERS];
} EXCEPTION_RECORD;
```

[docs.microsoft.com/en-us/windows/win32/api/winnt/ns-winnt-exception\\_record](https://docs.microsoft.com/en-us/windows/win32/api/winnt/ns-winnt-exception_record)

# EXCEPTION\_RECORD x86/x64

```
typedef struct _EXCEPTION_RECORD32 {  
    DWORD    ExceptionCode;  
    DWORD    ExceptionFlags;  
    DWORD    ExceptionRecord;  
    DWORD    ExceptionAddress;  
    DWORD    NumberParameters;  
    DWORD    ExceptionInformation[EXCEPTION_MAXIMUM_PARAMETERS];  
} EXCEPTION_RECORD32, *PEXCEPTION_RECORD32;
```

```
typedef struct _EXCEPTION_RECORD64 {  
    DWORD    ExceptionCode;  
    DWORD    ExceptionFlags;  
    DWORD64  ExceptionRecord;  
    DWORD64  ExceptionAddress;  
    DWORD    NumberParameters;  
    DWORD    __unusedAlignment;  
    DWORD64  ExceptionInformation[EXCEPTION_MAXIMUM_PARAMETERS];  
} EXCEPTION_RECORD64, *PEXCEPTION_RECORD64;
```

[docs.microsoft.com/en-us/windows/win32/api/winnt/ns-winnt-exception\\_record](https://docs.microsoft.com/en-us/windows/win32/api/winnt/ns-winnt-exception_record)

# Where to start ?

So, how do we get this **PCONTEXT** ?

**#if \_MSC\_VER >= 1900**  
(Visual Studio 2015-19)

# Where to start ?

So, how do we get this **PCONTEXT** ?

**#if \_MSC\_VER >= 1900**  
(Visual Studio 2015-19)

**PCONTEXT ExceptionHandling::GetCurrentExceptionContext()**

{

    \_\_vcrt\_ptd \* pTid = nullptr;

**#ifdef \_DLL // Multi-Threaded DLL /MD or /MDd**

    pTid = (\_\_vcrt\_ptd \*)(((BYTE \*)\_\_current\_exception\_context())  
                        - offsetof(\_\_vcrt\_ptd, \_curcontext));

**#else // Multi-Threaded /MT or /MTd**

    pTid = \_\_vcrt\_getptd();

**#endif**

    return (CONTEXT \*)pTid->\_curcontext;

}

# Where to start ?

So, how do we get this **PCONTEXT** ?

**#if \_MSC\_VER < 1900**  
(Visual Studio 2013)

# Where to start ?

So, how do we get this **PCONTEXT** ?

**#if \_MSC\_VER < 1900**  
(Visual Studio 2013)

```
PCONTEXT ExceptionHandling::GetCurrentExceptionContext()
{
    _tiddata * pTid = nullptr;

#ifdef _DLL // Multi-Threaded DLL /MD or /MDd

    pTid = (_tiddata *)(((BYTE *)__pxcptinfoptrs())
                         - offsetof(_tiddata, __pxcptinfoptrs));

#else // Multi-Threaded /MT or /MTd

    pTid = __getptd();

#endif

    return (CONTEXT *)pTid->_curcontext;
}
```

# CRT Power

```
#include <eh.h>

#include <signal.h> // for use of API void ** __pxcptinfoptrs()

#if _MSC_VER >= 1900

#include <../CRT/src/vcruntime/vcruntime_internal.h>

extern "C" __vcrt_ptd * __cdecl __vcrt_getptd();
extern "C" void ** __cdecl __current_exception_context();

#else

// for use of (private) API _tiddata * _getptd()
#include <../CRT/src/mtdll.h>

#endif
```

# CRT Power

```
// per-thread data
typedef struct __vcrt_ptd // #include <../CRT/src/vcruntime/vcruntime_internal.h>
{
    // C++ Exception Handling (EH) state
    unsigned long      _NLG_dwCode;           // Required by NLG routines
    unexpected_handler _unexpected;          // unexpected() routine
    void *              _translator;          // S.E. translator
    void *              _purecall;            // called when pure virtual happens
    void *              _curexception;         // current exception
    void *              _curcontext;           // current exception context
    int                 _ProcessingThrow;       // for uncaught_exception
    void *              _curexcspec;           // for handling exceptions thrown from std::unexpected
    int                 _cxxReThrow;            // true if it's a rethrown C++ exception

#if defined _M_X64 || defined _M_ARM || defined _M_ARM64
    void *              _pExitContext;
    void *              _pUnwindContext;
    void *              _pFrameInfoChain;
    uintptr_t            _ImageBase;
    uintptr_t            _ThrowImageBase;
    void *              _pForeignException;
#elif defined _M_IX86
    void *              _pFrameInfoChain;
#endif
} __vcrt_ptd;
```

# Caller PCONTEXT ...

What if we want to get the current StackTrace from the *context of the caller* ?  
(on demand - eg. assertions, logging)

When **no exception** is in flight!

How to get the **caller's PCONTEXT** ?

## Caller PCONTEXT ...

```
void StackWalker::TraceFromCaller(wstring & aStackMsg)
{
    using PF_RtlCaptureContext = void(WINAPI *)(PCONTEXT aContextRecord);

    // dynamically load the RtlCaptureContext() kernel API
    static auto CaptureCtx = (PF_RtlCaptureContext)::GetProcAddress(
        ::LoadLibraryA("Kernel32.dll"), "RtlCaptureContext");

    CONTEXT context;
    ::ZeroMemory(&context, sizeof(context));

    // retrieve the context record of the caller function
    CaptureCtx(&context);

    StackWalker::TraceFromContext(aStackMsg, &context);
}
```

# PCONTEXT ...

So now we know how to get this PCONTEXT  
How do we *walk the stack* ?

```
wstring stackTrace;  
StackWalker::TraceFromContext(stackTrace, GetCurrentExceptionContext());
```

# Walk the stack - init

```
void StackWalker::TraceFromContext(wstring & aStackMsg, PCONTEXT aContext, int MaxFrameCount)
{
    // All <DbgHelp> functions, such as StackWalk(), are single threaded.
    // (calls from more than one thread to this function will likely result
    // in unexpected behavior or memory corruption)
    // => we must synchronize all concurrent calls to this function
    SyncGuard guard(sEHSyncSupport);

    // Copy the given machine CONTEXT structure because the StackWalk() API
    // might modify it and subsequent calls needing the CONTEXT will fail
    CONTEXT context;
    ::CopyMemory(&context, aContext, sizeof(context));

    HANDLE hProcess = ::GetCurrentProcess();
    HANDLE hThread = ::GetCurrentThread();

    // create a symbol explorer
    SymbolUtil symMgr;
    if (!symMgr.Init(hProcess))
        return;

    ...
}
```

# Walk the stack

```
void StackWalker::TraceFromContext(wstring & aStackMsg, PCONTEXT aContext, int MaxFrameCount)
{
    ...

    // initialize the STACKFRAME according to the platform we are working on (PE type)
    STACKFRAME sf;
    DWORD imageType = InitStackFrameFromContext(&sf, &context);

    for (int frmIndex = 0; frmIndex < MaxFrameCount; frmIndex++)
    {
        // get the current frame info
        BOOL result = ::StackWalk(imageType, hProcess, hThread, &sf, &context, nullptr,
                                  SymFunctionTableAccess, SymGetModuleBase, nullptr);
        if (!result)
            break;

        aStackMsg += symMgr.ComposeStackFrame(sf.AddrPC.Offset);
    }

    // write the module load address - needed because of ASLR (Address Space Layout Randomization)
    aStackMsg += symMgr.ComposeModuleBaseAddress();
}
```

# Walk the stack - frame setup

```
DWORD InitStackFrameFromContext(LPSTACKFRAME aStackFrame, PCONTEXT aContext)
{
    ::ZeroMemory(aStackFrame, sizeof(STACKFRAME));

#ifndef _M_IX86

    DWORD imageType = IMAGE_FILE_MACHINE_I386;

    aStackFrame->AddrStack.Offset = aContext->Esp;
    aStackFrame->AddrStack.Mode = AddrModeFlat;

    aStackFrame->AddrFrame.Offset = aContext->Ebp;
    aStackFrame->AddrFrame.Mode = AddrModeFlat;

    aStackFrame->AddrPC.Offset = aContext->Eip;
    aStackFrame->AddrPC.Mode = AddrModeFlat;

#endif // _M_IX86

    .....

#endif // _M_X64

    return imageType;
}
```

# Walk the stack - frame setup

```
DWORD InitStackFrameFromContext(LPSTACKFRAME aStackFrame, PCONTEXT aContext)
{
    ::ZeroMemory(aStackFrame, sizeof(STACKFRAME));

#ifndef _M_IX86

    DWORD imageType = IMAGE_FILE_MACHINE_I386;

    aStackFrame->AddrStack.Offset = aContext->Esp;
    aStackFrame->AddrStack.Mode = AddrModeFlat;

    aStackFrame->AddrFrame.Offset = aContext->Ebp;
    aStackFrame->AddrFrame.Mode = AddrModeFlat;

    aStackFrame->AddrPC.Offset = aContext->Eip;
    aStackFrame->AddrPC.Mode = AddrModeFlat;

#endif // _M_IX86

    .....

#endif // _M_IX86

    return imageType;
}
```

```
#elif defined _M_X64
```

```
    DWORD imageType = IMAGE_FILE_MACHINE_AMD64;

    aStackFrame->AddrStack.Offset = aContext->Rsp;
    aStackFrame->AddrStack.Mode = AddrModeFlat;

    aStackFrame->AddrFrame.Offset = aContext->Rbp;
    aStackFrame->AddrFrame.Mode = AddrModeFlat;

    aStackFrame->AddrPC.Offset = aContext->Rip;
    aStackFrame->AddrPC.Mode = AddrModeFlat;
```

```
#endif
```

# ASLR (Address Space Layout Randomization)

```
// Serialize module base address – needed because of ASLR

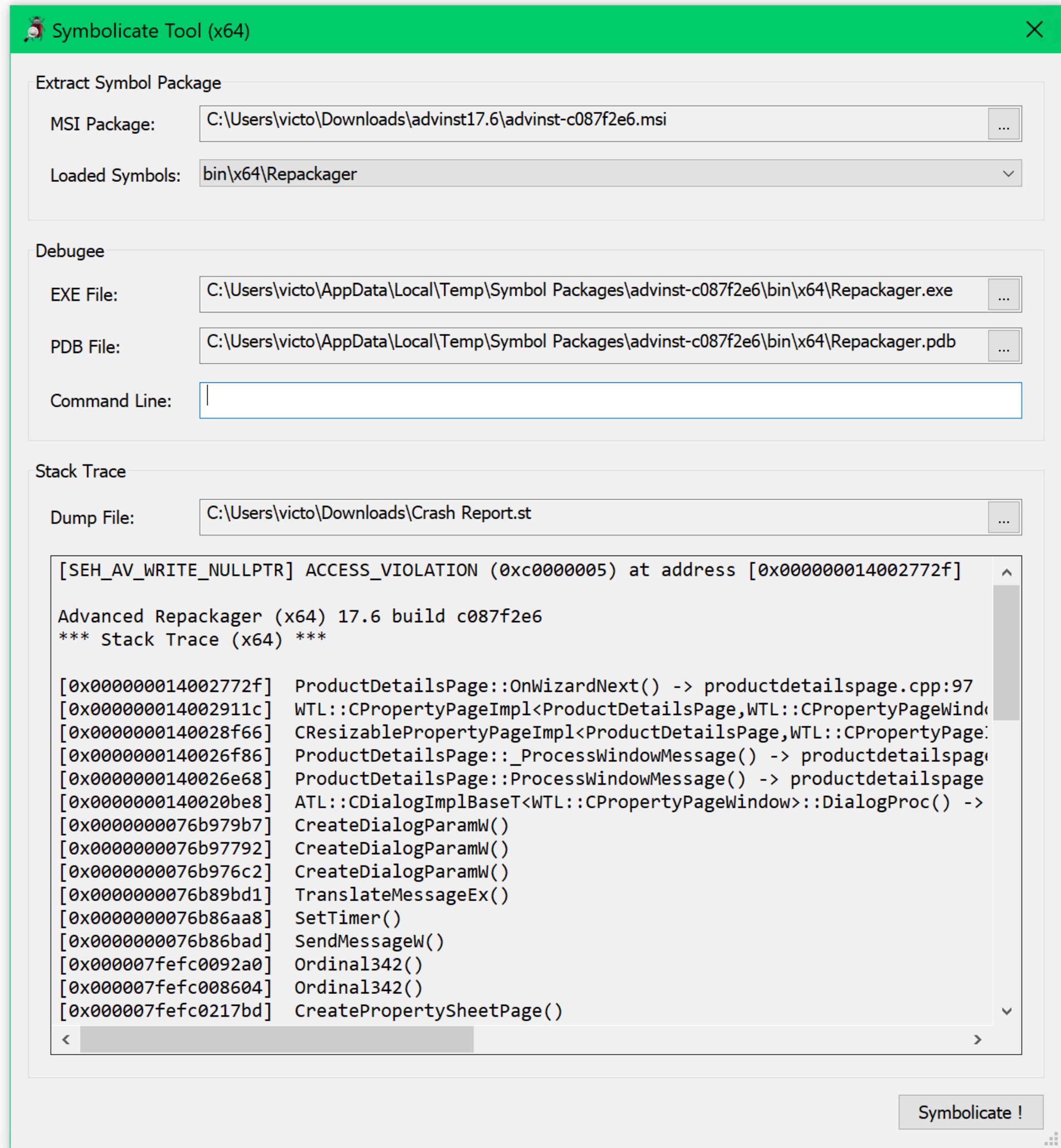
wstring SymbolUtil::ComposeModuleBaseAddress()
{
    wstring stackFrame;

    HMODULE moduleLoadAddress = ::GetModuleHandle(nullptr);

    wchar_t buf[MAX_PATH];
    swprintf_s(buf, MAX_PATH, ADDRESS_FORMAT L" ", (size_t) moduleLoadAddress);

    stackFrame += buf;
    stackFrame += SW_MODULE_LOAD_ADDRESS;
    stackFrame += SW_EOL;
    return stackFrame;
}
```

# Symbolicate Tool



← select build



Build artifacts

advinst-c087f2e6.dsym

← select crash report



← get a full stack trace

# Symbolicate Tool: arch PE/COFF

Symbolicate tool comes in two ISAs: **x86 & x64**

👉 must match the arch of the debugged process

```
CoffBrowse imageInfo(targetExePath);
```

```
if (!imageInfo.IsValidPE())
{
    Error("The selected file is not a valid Windows application.");
    return 0;
}
```

```
StackTraceAnalyzer analyzer(imageInfo.Is64());
```

```
#if defined _M_IX86
    if (imageInfo.Is64())
#elif defined _M_X64
    if (!imageInfo.Is64())
#endif
{
    Error("Process architecture mismatch (x86/x64). Launch the appropriate version of this tool.");
    return 0;
}
```

# Symbolicate Tool: launch debug session

```
// launch the process we want to debug (SEE_MASK_FLAG_NO_UI)
mDebugProcess = DebugProcessLaunch(exePath, exeCmd);

...
// get the load address of the debugged process – needed because of ASLR
// (Address Space Layout Randomization)
mDebugProcessBaseAddress = (DWORD_PTR)GetMainModuleForProcess(mDebugProcess);

// initialize the symbol handler for the process
mSymMgr.Init(mDebugProcess, symbolsPath);

...
// compose the symbolicated stack trace from the client crash report
mStackTrace = analyzer.Symbolicate(crashReport);
```

::EnumProcessModules()

# Symbol INIT

```
bool SymbolUtil::Init(HANDLE aProcess, const wstring & aSymbolsPath)
{
    // set debugging tools global options
    ::SymSetOptions(SYMOPT_UNDNAME | SYMOPT_DEFERRED_LOADS |
                    SYMOPT_LOAD_LINES | SYMOPT_DEBUG);

    // check if we can use debugging tools
    if (!IsAvailable())
        return false;

    // initialize the symbol handler for the given process
    BOOL symInit = ::SymInitialize(mProcess, nullptr, TRUE);
    assert(symInit == TRUE);
    if (!symInit)
        return false;

    // set the process module folder into the search paths for image symbols
    return SetSymbolSearchPath(aSymbolsPath);
}
```

[docs.microsoft.com/en-us/windows/win32/api/dbghelp/nf-dbghelp-symsetoptions](https://docs.microsoft.com/en-us/windows/win32/api/dbghelp/nf-dbghelp-symsetoptions)

# Symbol INIT

```
bool SymbolUtil::Init(HANDLE aProcess, const wstring & aSymbolsPath)
{
    // set debugging tools global options
    ::SymSetOptions(SYMOPT_UNDNAME | SYMOPT_DEFERRED_LOADS |
                    SYMOPT_LOAD_LINES | SYMOPT_DEBUG);

    // check if we can use debugging
    if (!IsAvailable())
        return false;

    // initialize the symbol handler for the given process
    BOOL symInit = ::SymInitialize(mProcess, nullptr, TRUE);
    assert(symInit == TRUE);
    if (!symInit)
        return false;

    // set the process module folder into the search paths for image symbols
    return SetSymbolSearchPath(aSymbolsPath);
}
```

```
PF_SymFromAddr DynSymFromAddr() {
    static auto symProc = (PF_SymFromAddr)::GetProcAddress(
        ::LoadLibraryA("Dbghelp.dll"), "SymFromAddr");
    return symProc;
}
```

[docs.microsoft.com/en-us/windows/win32/api/dbghelp/nf-dbghelp-symsetoptions](https://docs.microsoft.com/en-us/windows/win32/api/dbghelp/nf-dbghelp-symsetoptions)

# Symbol Search Path

```
bool SymbolUtil::SetSymbolSearchPath(wstring symbolSearchPath)
{
    if (symbolSearchPath.empty())
    {
        // set the process module folder into the search paths for image symbols
        char modulePath[MAX_PATH];
        ::GetModuleFileName(nullptr, modulePath, MAX_PATH);

        symbolSearchPath = modulePath;
        const size_t pos = symbolSearchPath.find_last_of('\\');
        if (pos != string::npos)
            symbolSearchPath = symbolSearchPath.substr(0, pos);
    }

    // set the search paths for symbols (PDB)
    return ::SymSetSearchPath(mProcess, symbolSearchPath.c_str()) == TRUE;
}
```

# Symbolicate Tool

```
wstring StackTraceAnalyzer::Symbolicate(const wstring & aRawCrashReport)
{
    ...

    auto stackFrames = GetFrames(aRawCrashReport);

    // extract stack trace BaseAddress (should be the last line in the trace)
    mStackTraceBaseAddress = GetFrameAddress(stackFrames[0]);

    ...

    // symbolicate each frame
    for (const auto & frame : stackFrames)
        processedStackTrace += ProcessStackFrame(frame);

    return processedStackTrace;
}
```

# Symbolicate Tool: Process Stack Frame

```
wstring StackTraceAnalyzer::ProcessStackFrame(const StackFrame & aStackFrame)
{
    ...
    // extract stack frame address to symbolicate
    DWORD_PTR frameAddress = GetFrameAddress(aStackFrame);

    if (aStackFrame == SW_MODULE_LOAD_ADDRESS)
        return; // don't translate module base address
    if (aStackFrame != SW_NO_SYMBOL)
        return; // only symbolicate frames with no symbols

    // REBASE: perform address translation
    // needed because of ASLR (Address Space Layout Randomization)
    DWORD_PTR realAddress = frameAddress +
                           (mDebugProcessBaseAddress - mStackTraceBaseAddress);

    // symbolicate stack frame with the debug information
    // of the instrumented process
    return mSymMgr.ComposeStackFrame(realAddress);
}
```

# Walk the stack - SymbolUtil

```
wstring SymbolUtil::ComposeStackFrame(DWORD_PTR aAddress)
{
    wstring stackFrame;

    wchar_t buf[MAX_PATH];
    swprintf_s(buf, MAX_PATH, ADDRESS_FORMAT L" ", aAddress);
    stackFrame += buf;

    // retrieve symbol name
    stackFrame += SymbolNameFromAddress(aAddress);

    // source filename:line
    const wstring & origin = SymbolSourceFromAddress(aAddress);
    if (!origin.empty())
        stackFrame += origin;

    return stackFrame;
}
```

# Walk the stack - SymbolUtil

```
wstring SymbolUtil::SymbolNameFromAddress(DWORD_PTR aAddress) const
{
    ...
    auto pSymbol = reinterpret_cast<PSYMBOL_INF0>(mSymMemBuffer);
    pSymbol->SizeOfStruct = sizeof(SYMBOL_INF0);

    // get symbol name (de-mangled function name)
    if (DynSymFromAddr(mProcess, aAddress, nullptr, pSymbol))
        return pSymbol->Name;
    else
        return SW_NO_SYMBOL;
}
```

```
PF_SymFromAddr DynSymFromAddr()
{
    static auto symProc = (PF_SymFromAddr)::GetProcAddress(
        ::LoadLibraryA("Dbghelp.dll"), "SymFromAddr");

    return symProc;
}
```

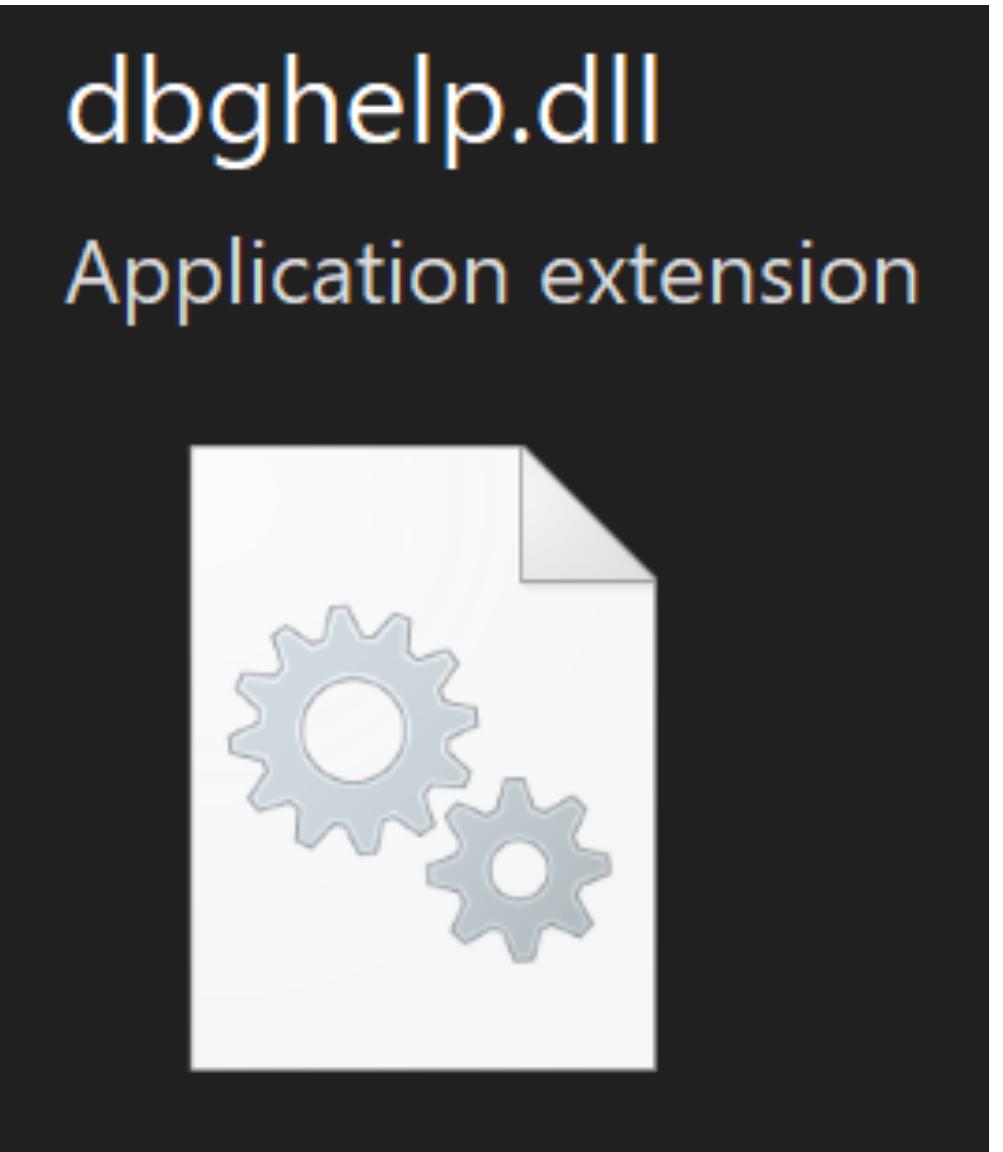
# Walk the stack - SymbolUtil

```
wstring SymbolUtil::SymbolSourceFromAddress(DWORD_PTR aAddress) const
{
    DWORD displacement = 0;

    IMAGEHELP_LINE line;
    ::ZeroMemory(&line, sizeof(line));
    line.SizeOfStruct = sizeof(line);

    // get location information for symbol "sourceFile:lineNo"
    if (::SymGetLineFromAddr(mProcess, aAddress, &displacement, &line))
    {
        wchar_t origin[MAX_PATH];
        swprintf_s(origin, MAX_PATH, L"%s:%ld", line.FileName, line.LineNumber);
        return origin;
    }
}
```

# <dbghelp.h>



x86/x64

`#include <dbghelp.h>`

`/LINK Dbghelp.lib`

Dynamic dependency on `Dbghelp.dll`

**An good in-the-box  
alternative**



# VS 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.

Changes the way you report a bug, in general

**+ Live Share**

# VS Snapshot File

ShareSource.dmp ShareSource App.g.i.cs App.xaml.cs

### Minidump File Summary

11/5/2018 4:00:16 PM

#### Dump Summary

- Dump File ShareSource.dmp : C:\User  
Last Write Time 11/5/2018 4:00:16 PM
- Process Name ShareSource.exe : C:\Users\x64
- Process Architecture x64
- Exception Code 0x80000004
- Exception Information A trace trap or other single-step
- Heap Information Present
- Error Information

#### System Information

- OS Version 10.0.17763
- CLR Version(s) 4.6.26702.0

#### Modules

Module Name	Module
ShareSource.exe	1.0.0.0
ntdll.dll	10.0.177
kernel32.dll	10.0.177

Search

Module Name

File Edit View Project Build Debug Test Analyze Tools Window Help Solution1 D16.0STG | ADMIN

Process: 7f1e33c6-68ba-406b-9095-a4b: Lifecycle Events Thread: [7084] Main Thread Stack Frame: main

HeapCorruptionSample.cpp 7f1e33c6-68ba-406b-9095-a4b:txt.dmp (Global Scope)

109 CloseHandle(FileHandle);  
110 void\* freed\_pointer = malloc(100);  
111 free(freed\_pointer); //we'll never get here either  
112 if (array[0] == 'a') {  
113 if (array[1] == 'b') {  
114 if (array[2] == 'c') {  
115 if (array[3] == 'd') {  
116 if (array[4] == 'e') {  
117 if (array[5] == 'f') {  
118 if (array[6] == 'g') {  
119 if (array[7] == 'h') {  
120 if (array[8] == 'i') {  
121 if (array[9] == 'j') {  
122 if (array[10] == 'k' & array[38] == 'g' & array[100] == 'b') {  
123 \*((int\*)freed\_pointer) = 0x1c0debad; //uaf  
124 else if (array[23] == '\xba') {  
125 free(freed\_pointer); //double free  
126 }  
127 else if (strstr(array, "short")) {  
128 printf("we'll never get here either");  
129 }  
130 }  
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# Snapshot Loaded

The screenshot shows a Visual Studio interface with the following details:

- Title Bar:** File, Edit, View, Project, Build, Debug, Test, Analyze, Tools, Extensions, Window, Help, Search Visual Studio (Ctrl+Q).
- Solution Explorer:** Solution1, D16.0STG | ADMIN.
- Process:** 7f1e33c6-68ba-406b-9095-a4b1.
- Lifecycle Events:** Thread: [7084] Main Thread.
- Stack Frame:** main.
- Code Editor:** HeapCorruptionSample.cpp, line 109. The code contains a stack corruption vulnerability.
- Exception Unhandled Dialog:** ASAN Error: Stack Buffer Overflow. It includes links to AzureMachine Bucket 0-3, Manage Job Submission, and Exception Settings.
- Output Window:** Shows assembly dump starting at address 0x3019fef0.
- Locals Window:** Shows variables: argc (2), argv (0x04301adc), array (0x00cff6c4), FileHandle (0x00000000), freed\_pointer (0x00000000), and readBytes (27).
- Live Share:** A large blue arrow points from the exception dialog to the "Start collaboration session..." link in the dialog, with the text "Live Share" overlaid.

Live Share

## **Part III**

# **Post-pandemic crashes**

P0881

A Proposal to add stacktrace library

- *Alexey Gorgurov, Antony Polukhin*

First draft: 2018-01-23 [R0]

based on [Boost.Stacktrace](#)

....

Didn't make into **C++20** 😞

...

[R7]

[wg21.link/P0881](#)

`#include <stacktrace>`

# Naming is hard

- 10 stacktrace
- 8 backtrace
- 1 back\_trace
- 1 stack\_trace
- 5 traceback
- 3 call\_stack
- 4 call\_trace
- 1 call\_history

[github.com/cplusplus/papers/issues/119](https://github.com/cplusplus/papers/issues/119)

# Naming is hard

- 2 `stack_frame`
- 3 `invocation_info`
- 9 `stacktrace::entry`
- 3 `stacktrace::frame`
- 5 `stacktrace_entry`
- 1 `stacktrace_frame`
- 2 `frame_descriptor`
- 4 `call_info`
- 2 `call_descriptor`
- 2 `frame_info`

[github.com/cplusplus/papers/issues/119](https://github.com/cplusplus/papers/issues/119)

The first major library feature for #Cpp23 will be a stack trace library

7:34 PM · Nov 9, 2020 · Twitter Web App

1 Quote Tweet 18 Likes

Kilian @kilian\_ukilele · Nov 10  
Replying to @AlisdairMered  
Awesome! Will std::exception also get a function to query the callstack from where it got thrown?

[twitter.com/alisdairmered/status/1325854252338716672?s=21](https://twitter.com/alisdairmered/status/1325854252338716672?s=21)

# C++ 23 <stacktrace>

Key features (desired):

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- all functions are **lazy**: do not query the stacktrace entry info without explicit request

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## Key features (desired):

- all functions are **lazy**: do not query the stacktrace entry info without explicit request
- **dynamic size** for trace - all the available invokers must be stored in a stacktrace
- implementations: allow to **disable/enable** gathering stacktraces by a linker switch
- stacktracing shouldn't prevent any of **optimizations**
- stacktrace should be **usable** in contract violation handler, coroutines, handler functions, parallel algorithms

# C++ 23 <stacktrace>

Key features (desired):

# C++ 23 <stacktrace>

Key features (desired):

# C++ 23 <stacktrace>

Key features (desired):

- `stacktrace_entry::description()` should return a **demangled** function signature

# C++ 23 <stacktrace>

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- information about **inlined functions** that have no separate stacktrace entries is welcomed -> `to_string(stacktrace)`

# C++ 23 <stacktrace>

## Key features (desired):

- `stacktrace_entry::description()` should return a **demangled** function signature
- `to_string(stacktrace)` should query information from **debug symbols**, symbol export tables and any other sources, returning *demangled* signatures
- information about **inlined functions** that have no separate stacktrace entries is welcomed -> `to_string(stacktrace)`
- avoid doing **heavy** operations in `basic_stacktrace` constructors or `stacktrace_entry::current()`

## C++ 23 <stacktrace>

```
class stacktrace_entry
{
public:
    using native_handle_type = implementation-defined;
    ...
    constexpr native_handle_type native_handle() const noexcept;
    constexpr explicit operator bool() const noexcept;
    ...
    string    description() const;
    string    source_file() const;
    uint32_t  source_line() const;
};
```

`stacktrace_entry` models concepts:  
`regular` and `three_way_comparable<strong_ordering>`

## C++ 23 <stacktrace>

```
template<class Allocator>
class basic_stacktrace
{
public:
    using value_type = stacktrace_entry;
    using allocator_type = Allocator;
    ...
    const_iterator begin() const noexcept;
    const_iterator end() const noexcept;
    const_reverse_iterator rbegin() const noexcept;
    const_reverse_iterator rend() const noexcept;
    ...

private:
    vector<value_type, allocator_type> m_frames;
};
```

## C++ 23 <stacktrace>

```
static basic_stacktrace current(const allocator_type& alloc = allocator_type()) noexcept;  
static basic_stacktrace current(size_type skip,  
                                const allocator_type& alloc = allocator_type()) noexcept;  
static basic_stacktrace current(size_type skip, size_type max_depth,  
                                const allocator_type& alloc = allocator_type()) noexcept;
```

=> **basic\_stacktrace** object with **m\_frames** storing the stack trace of  
the current evaluation in the *current thread* of execution

alloc is passed to the constructor of the **m\_frames** object.

# C++ 23 <stacktrace>

```
namespace std {  
  
    using stacktrace = basic_stacktrace<allocator<stacktrace_entry>>;  
  
    string to_string(const stacktrace_entry& f);  
    template<class Alloc>  
    string to_string(const basic_stacktrace<Alloc>& st);  
  
    template<class charT, class traits>  
    basic_ostream<charT, traits>&  
    operator<<(basic_ostream<charT, traits>& os, const stacktrace_entry& f);  
  
    template<class charT, class traits, class Alloc>  
    basic_ostream<charT, traits>&  
    operator<<(basic_ostream<charT, traits>& os, const basic_stacktrace<Alloc>& st);
```

description()  
source\_file()  
source\_line()

# C++ 23 Example

```
auto trace = basic_stacktrace::current();

for (stacktrace_entry frame : trace)
{
    std::cerr << frame.description() << " at "
                  << frame.source_file() << ":" << frame.source_line() << "\n";
}
```

# C++ 23 Example

```
auto trace = basic_stacktrace::current();

for (stacktrace_entry frame : trace)
{
    std::cerr << std::to_string(frame) << "\n";
}
```

# C++ 23 Example

```
auto trace = basic_stacktrace::current();

for (stacktrace_entry frame : trace)
{
    std::cerr << frame << "\n";
}
```

# C++ 23 Example

```
auto trace = basic_stacktrace::current();  
std::cerr << std::to_string(trace);
```

# C++ 23 Example

```
auto trace = basic_stacktrace::current();  
std::cerr << trace;
```

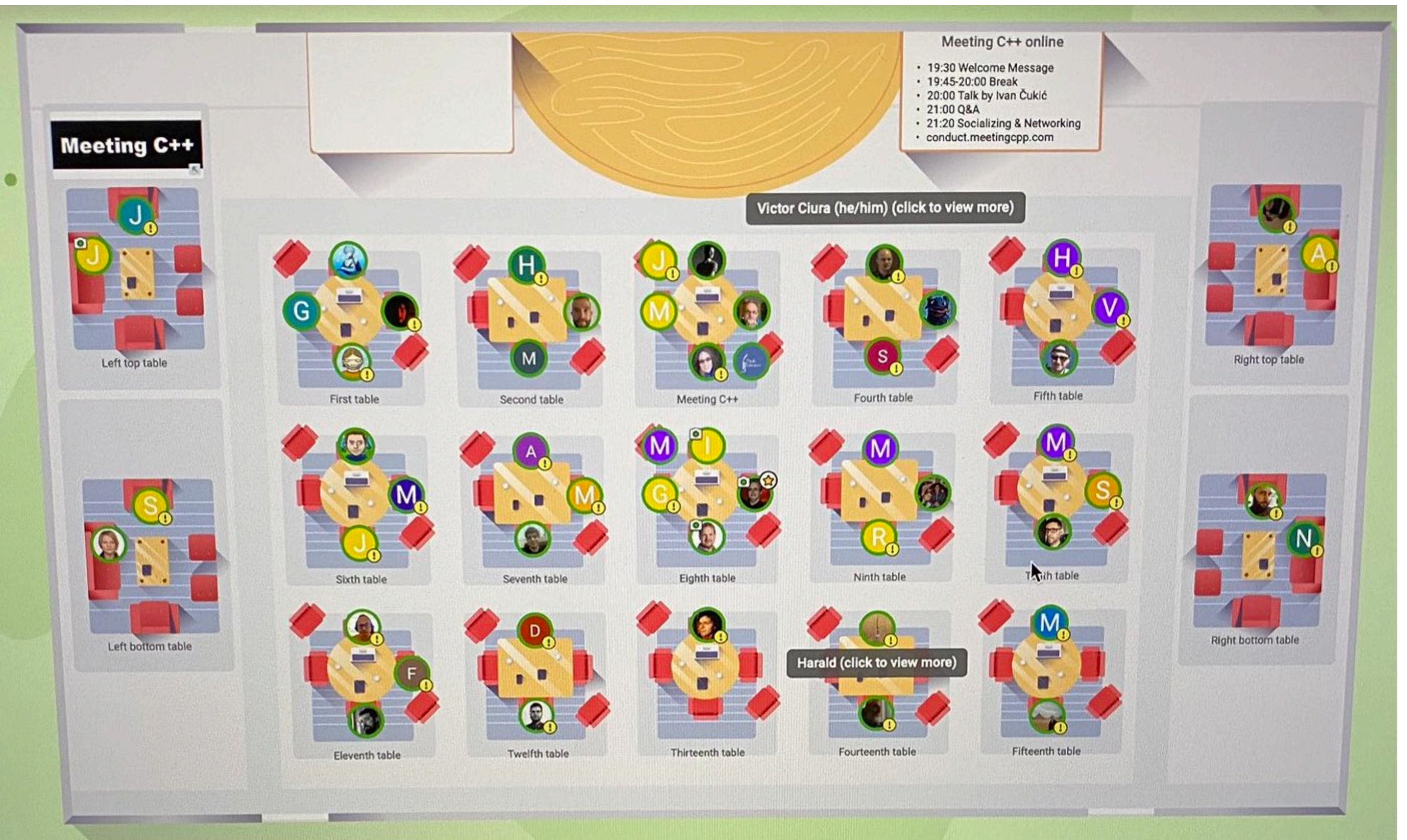
# C++ 23 <stacktrace>

It can't get any simpler than that.

# C++ 23 <stacktrace>

It can't get any simpler than that.

I can't wait to see **early** implementations from our standard library providers!



Q & A

# Symbolism: Rainbows and Crashes

**Meeting C++ 2020**

December 3<sup>rd</sup>



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