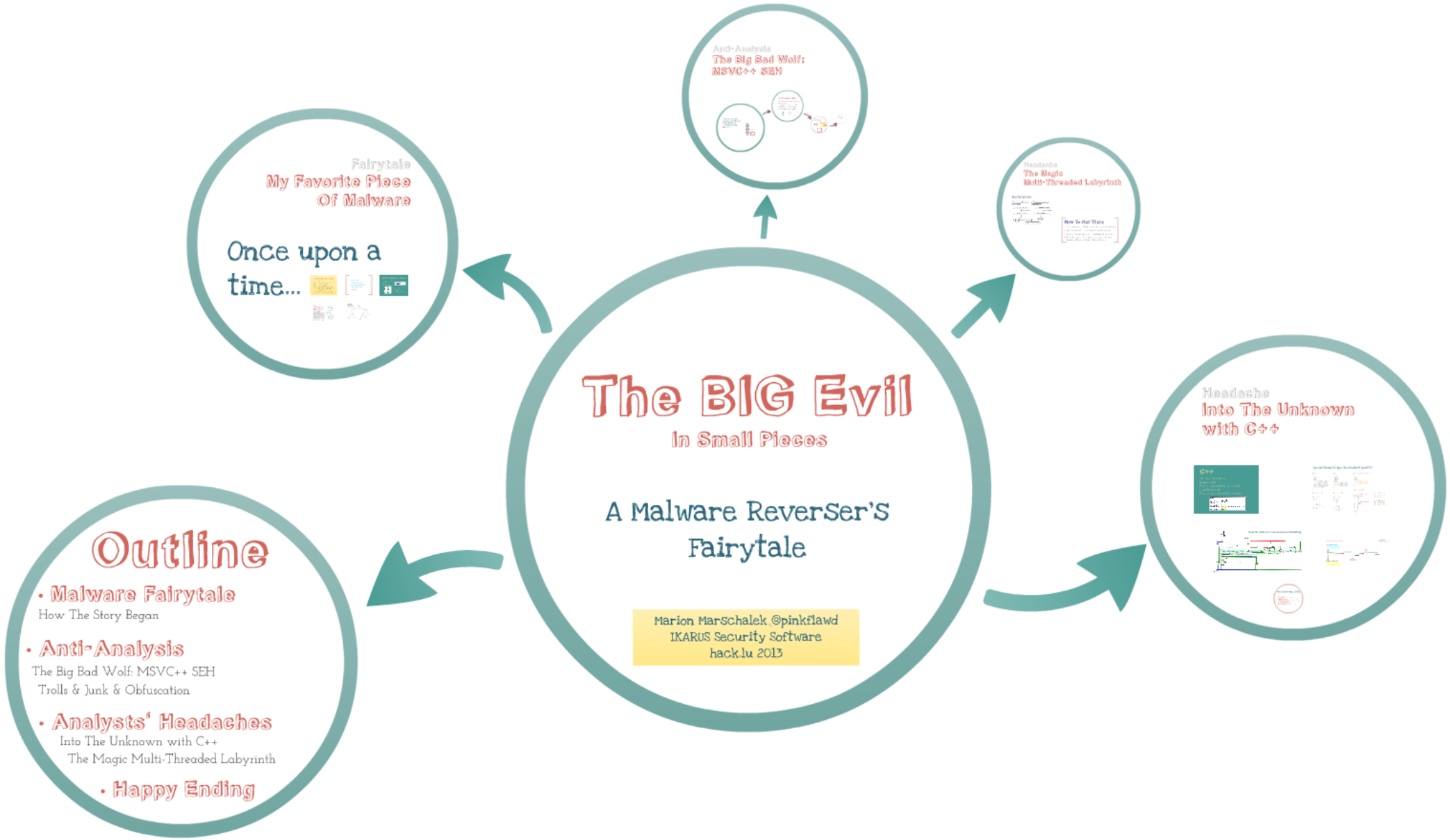

Anti-Analysis
The Big Bad Wolf:
MSVC++ SEH
Fairytale
My Favorite Piece
Of Malware
Once upon a
time...
Headache
The Magic
Multi-Threaded Labyrinth
The BIG Evil
In Small Pieces
A Malware ReverSer'S
Fairytale
Marion MarSchalek @pinkflawd
IKARUS Security Software
hack.lu 2013
Headache
Into The Unknown
with C++
Outline
• Malware Fairytale
How The Story Began
• Anti-Analysis
The Big Bad Wolf: MSVC++ SEH
Trolls & Junk & Obfuscation
• Analysts' Headaches
Into The Unknown with C++
The Magic Multi-Threaded Labyrinth
• Happy Ending

The BIG Evil

In Small Pieces

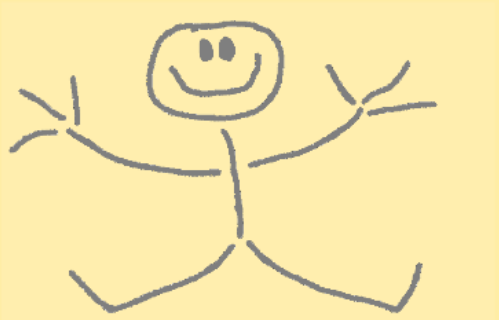
A Malware ReverSer'S Fairytale

Marion MarSchalek @pinkflawd
IKARUS Security Software
hack.lu 2013

me

Marion Marschalek
Malware Analyst

IKARUS security software



Twitter @pinkflawd

Reverse Engineering Hobbyist
Nut Cracker by Heart
Full-Contact Martial Artist

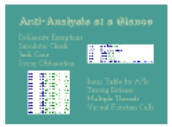
Outline

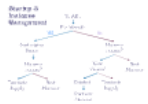
- **Malware Fairytale**
  - How The Story Began
- **Anti-Analysis**
  - The Big Bad Wolf: MSVC++ SEH
  - Trolls & Junk & Obfuscation
- **Analysts' Headaches**
  - Into The Unknown with C++
  - The Magic Multi-Threaded Labyrinth
- **Happy Ending**

Fairytale

My Favorite Piece Of Malware

Once upon a time...





A Fairytale in 5 Acts

1. Oh.. Anti-Analysis!
2. Oh.. It's Multi-Threaded!
3. Oh.. It's a File-Infector!
4. Crap.. Timing Defense, C++, Virtual Function Calls, Junk Code, Headache
5. HOORAY.. Got to the Core Functionality!!

An asian
multi-threaded
non-polymorphic
file-infecting
spy-bot.

Anti-Analysis at a Glance

Deliberate Exceptions
Simulator Check
Junk Code
String Obfuscation

```
lea     eax, [ebp+var_4]
push    eax
mov     eax, dword_43D190
mov     [ebp+var_4], '.'
mov     [ebp+var_3], '.'
mov     [ebp+var_2], '.'
call    dword ptr [eax+12Ch] ; gethost by name
```

```
push    edx
mov     [esp+4D4h+var_4B5], 'r'
mov     [esp+4D4h+var_4B4], 'l'
mov     [esp+4D4h+var_4B3], 'd'
mov     [esp+4D4h+var_4B2], ' '
mov     [esp+4D4h+var_4B1], 'o'
mov     [esp+4D4h+var_4B0], 'f'
mov     [esp+4D4h+var_4AF], ' '
mov     [esp+4D4h+var_4AE], 'w'
mov     [esp+4D4h+var_4AD], 'a'
mov     [esp+4D4h+var_4AC], 'r'
mov     [esp+4D4h+var_4AB], 'c'
mov     [esp+4D4h+var_4AA], 'r'
mov     [esp+4D4h+var_4A9], 'a'
mov     [esp+4D4h+var_4A8], 'f'
mov     [esp+4D4h+var_4A7], 't'
mov     [esp+4D4h+var_4A6], '\'
mov     [esp+4D4h+var_4A5], 0
```

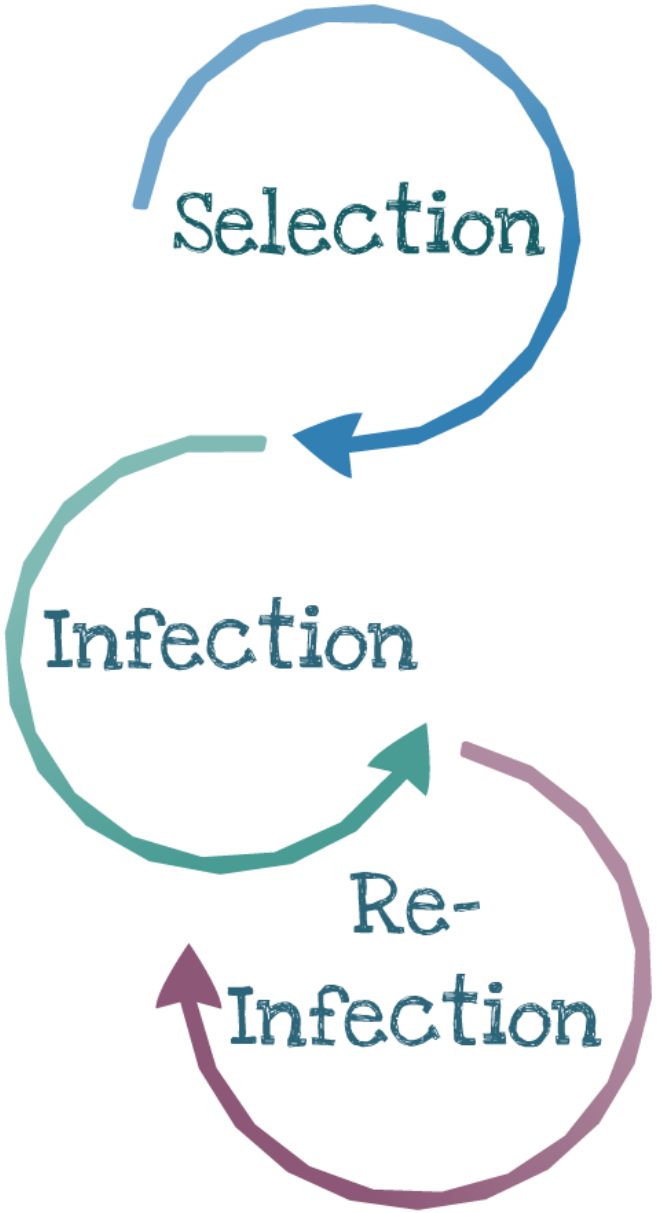
Jump Table for APIs
Timing Defense
Multiple Threads
Virtual Function Calls

Picky
Old-School File Infector

Filter Function

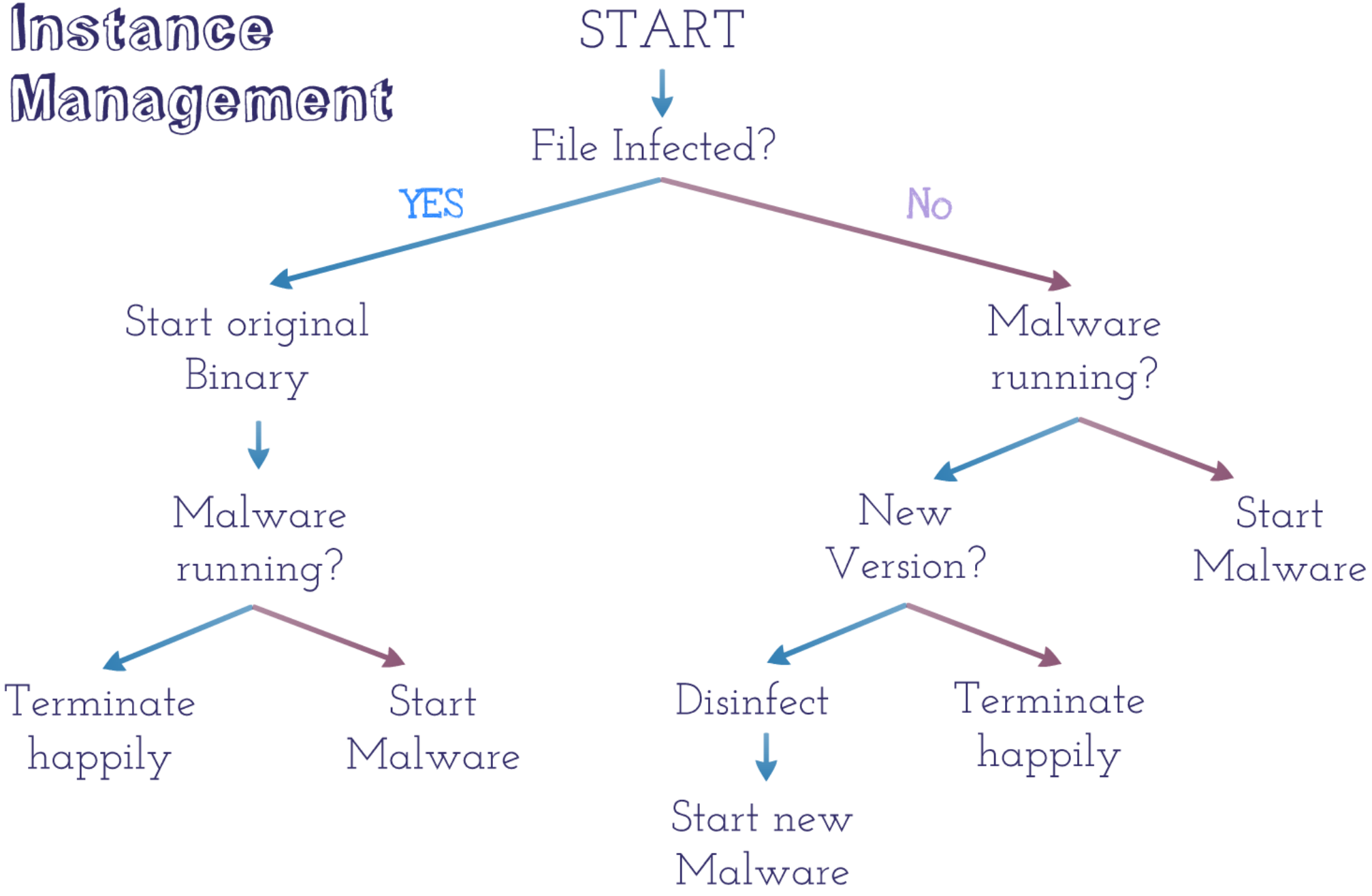
when Qihoo360 or Rising AV running
stop!
when process name contains
- netthief
- visual studio
- world of warcraft, ...

exclude!



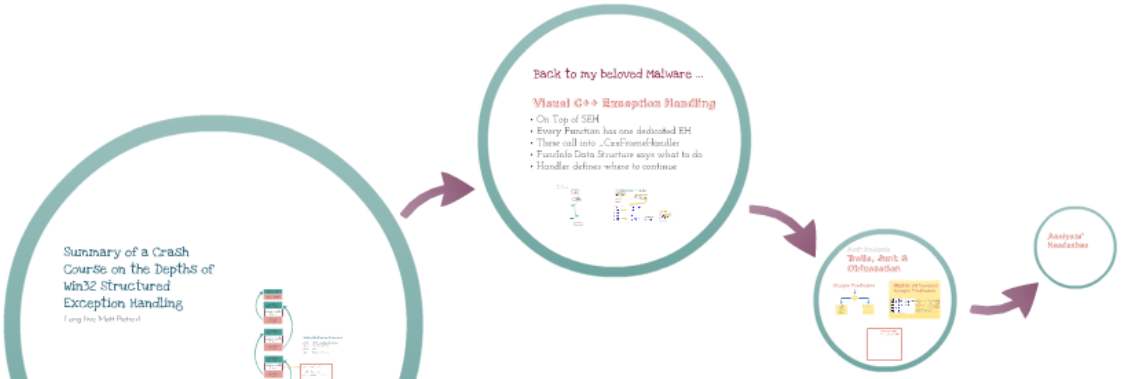
Now.. What does that mean?

Startup & Instance Management



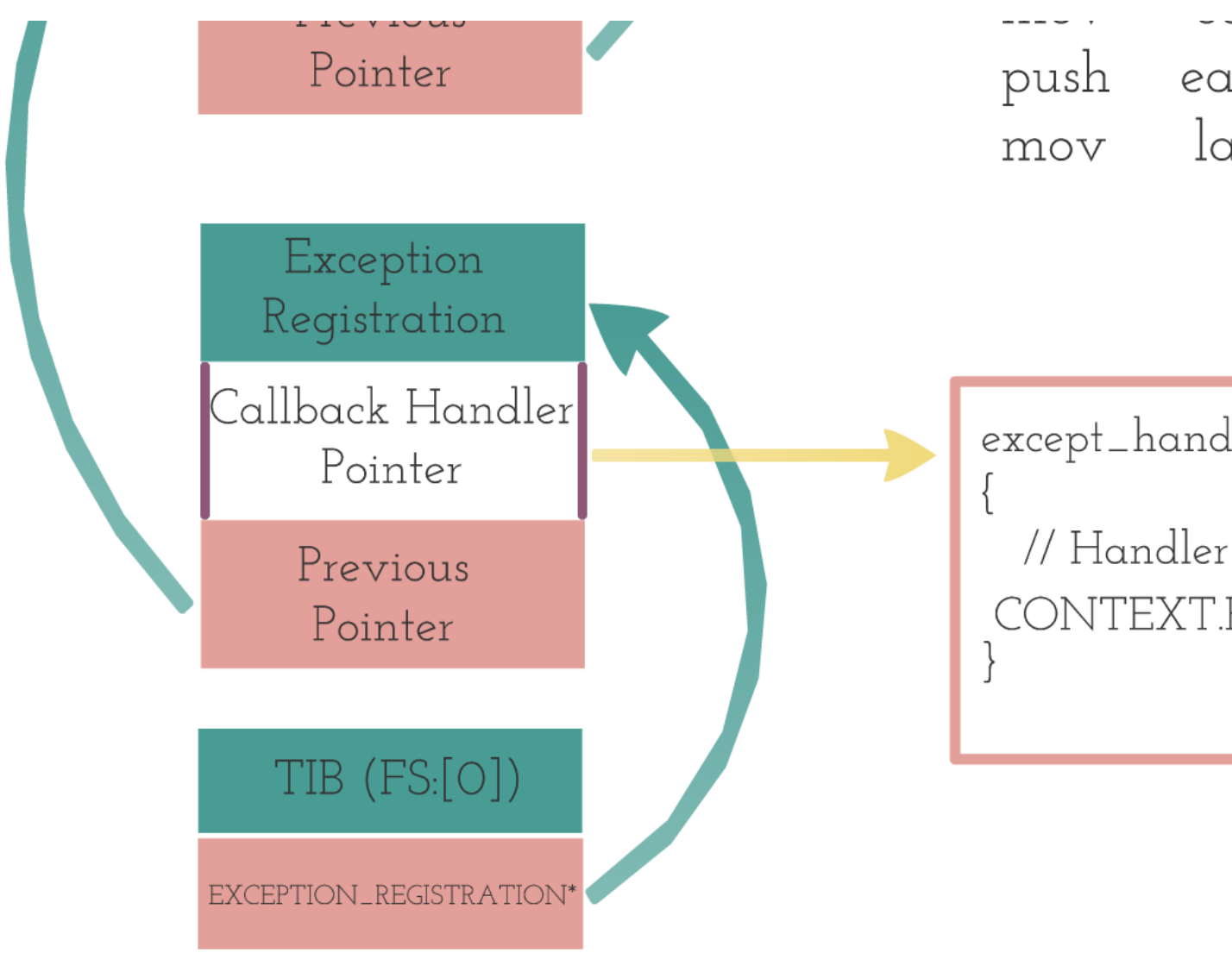
Anti-Analysis

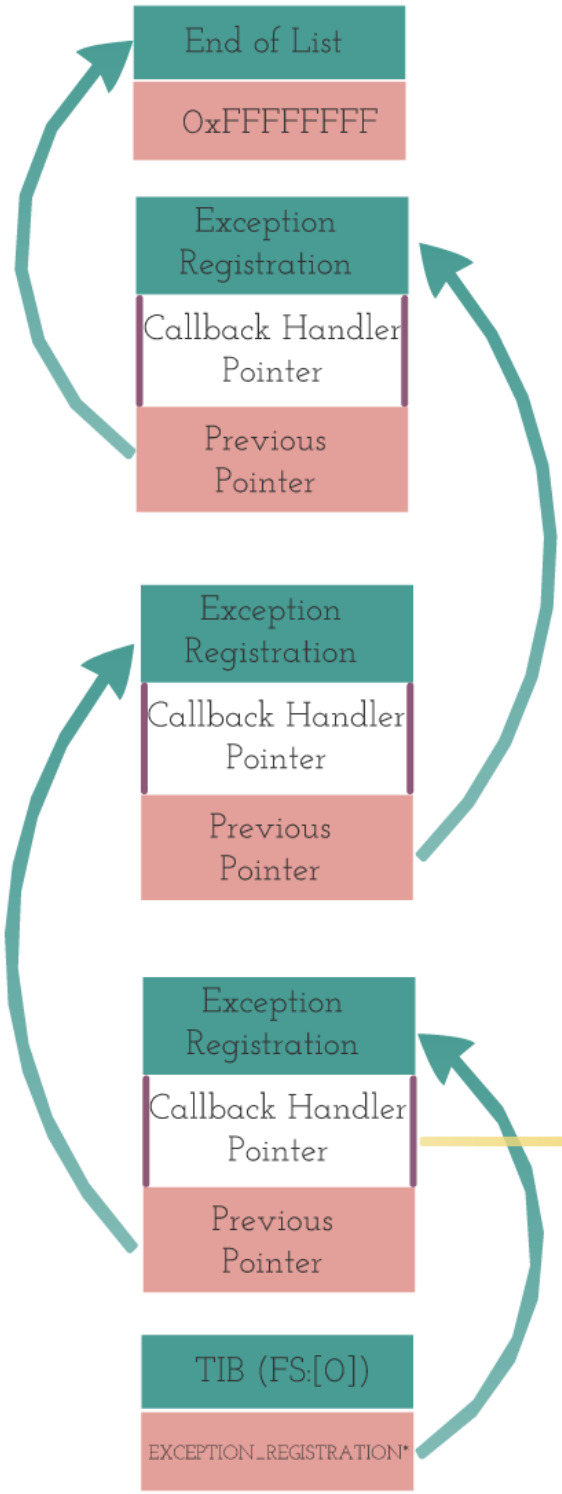
The Big Bad Wolf: MSVC++ SEH



Summary of a Crash Course on the Depths of Win32 Structured Exception Handling

Long live Matt Pietrek!

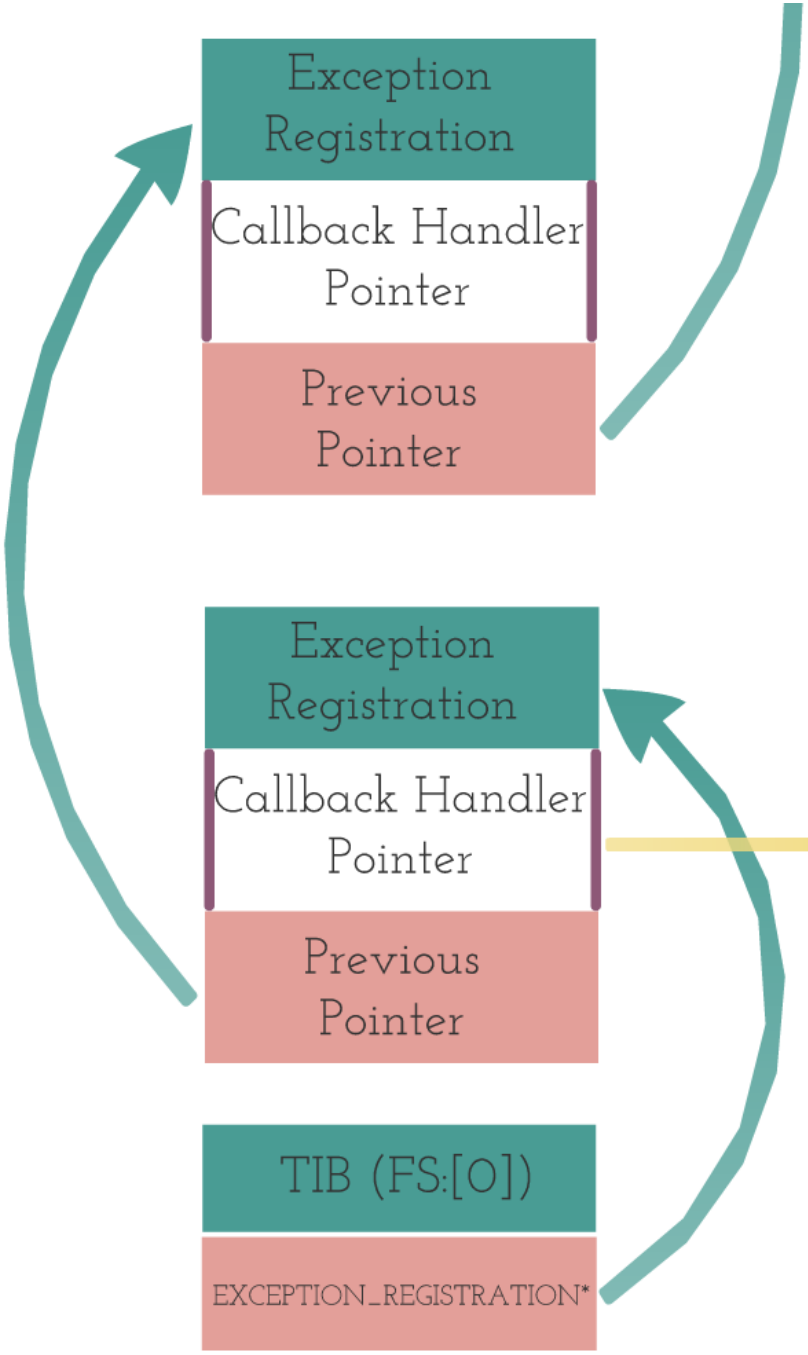

Pointer
Exception Registration
Callback Handler Pointer
Previous Pointer
TIB (FS:[0])
EXCEPTION_REGISTRATION*
except_hand
{
// Handler
CONTEXT.
}
push ea
mov la



EH-Registration for ReverserS:

```
push    offset _except_handler
mov     eax, large fs:0
push    eax
mov     large fs:0, esp
```

```
except_handler (...)
{
  // Handler Code
 CONTEXT.EIP = wonderland
}
```



EH-Registration for ReverSerS:

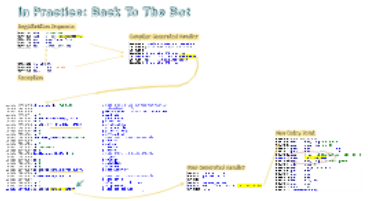
```
push    offset _except_handler
mov     eax, large fs:0
push    eax
mov     large fs:0, esp
```

```
except_handler (...)
{
   // Handler Code
 CONTEXT.EIP = wonderland
}
```

Back to my beloved Malware …

Visual C++ Exception Handling

- On Top of SEH
- Every Function has one dedicated EH
- These call into _CxxFrameHandler
- FuncInfo Data Structure says what to do
- Handler defines where to continue



Back to my beloved Malware …

Visual C++ Exception Handling

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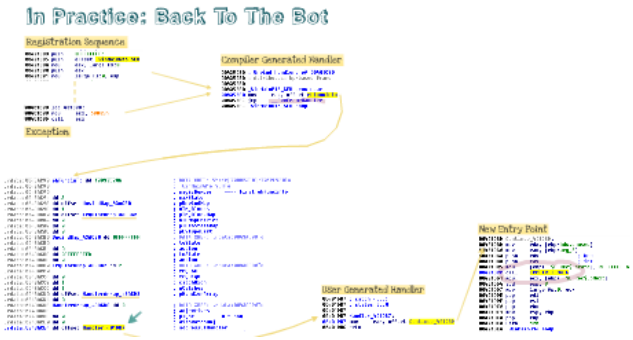
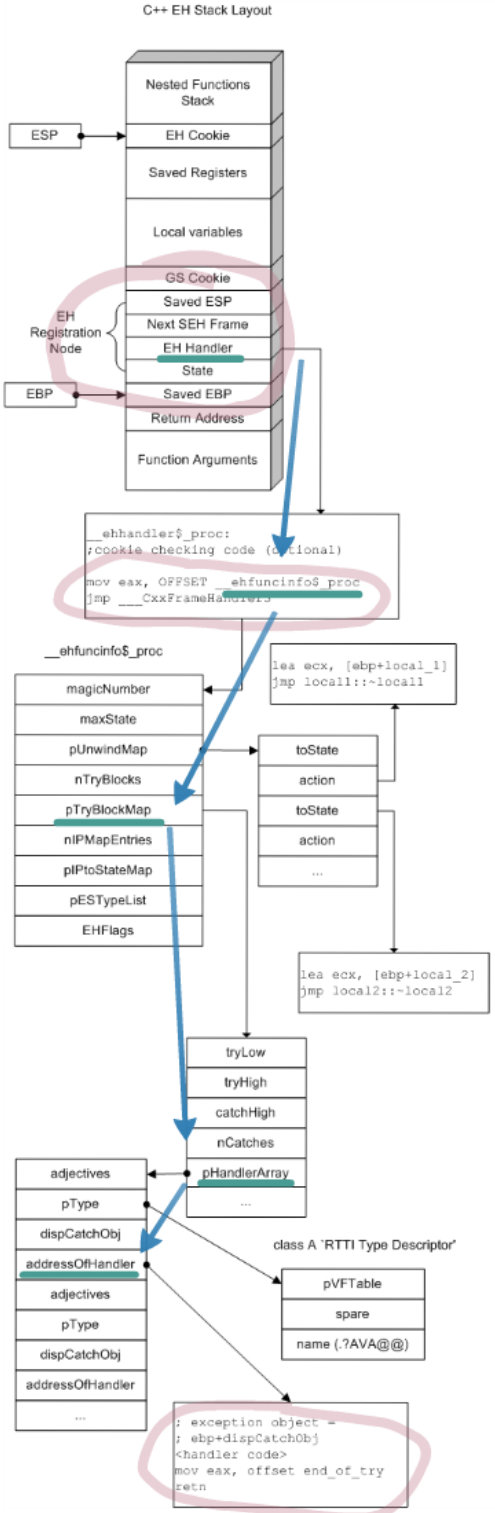
Thank you,
Igor & OpenRCE!

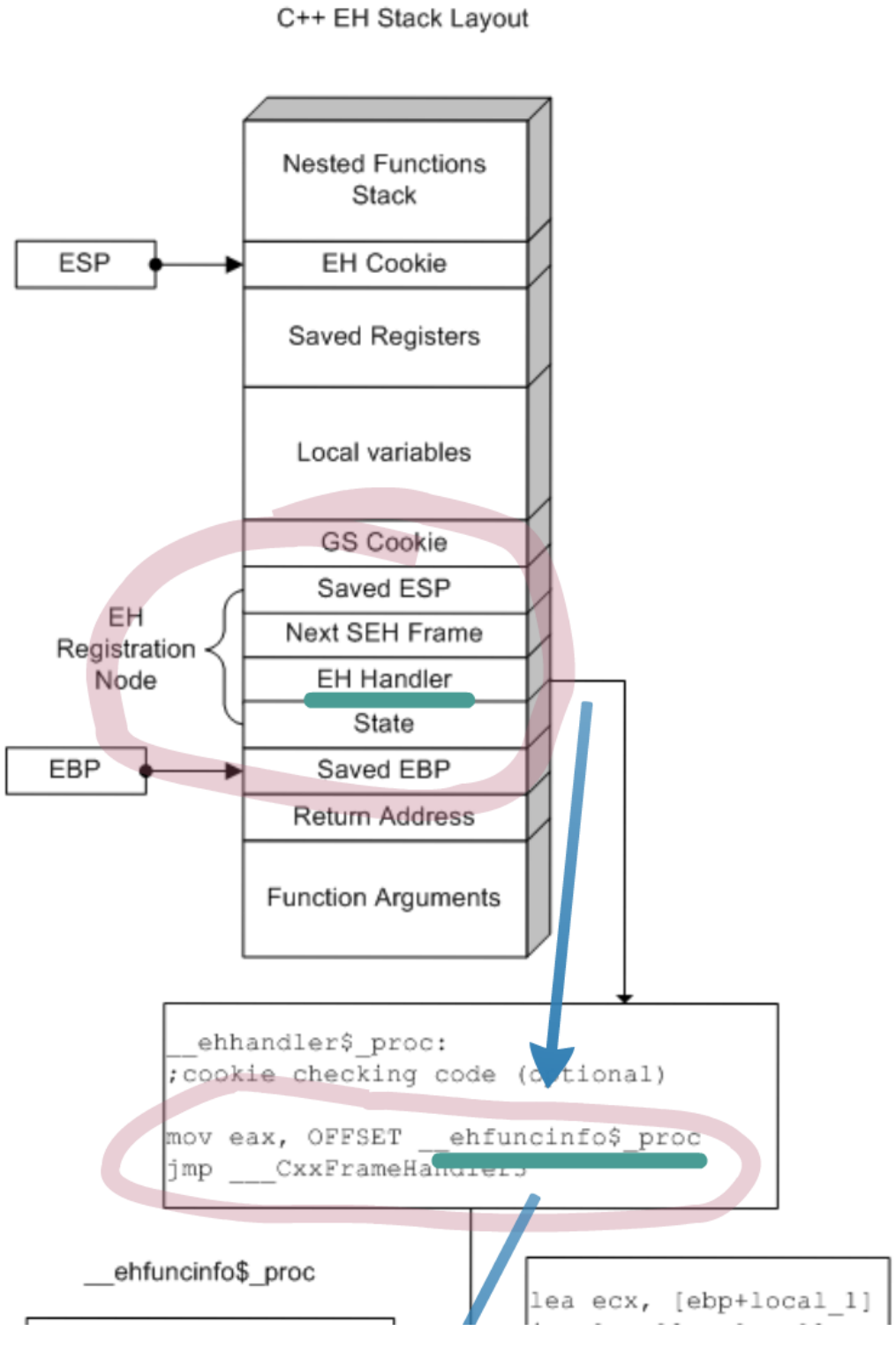


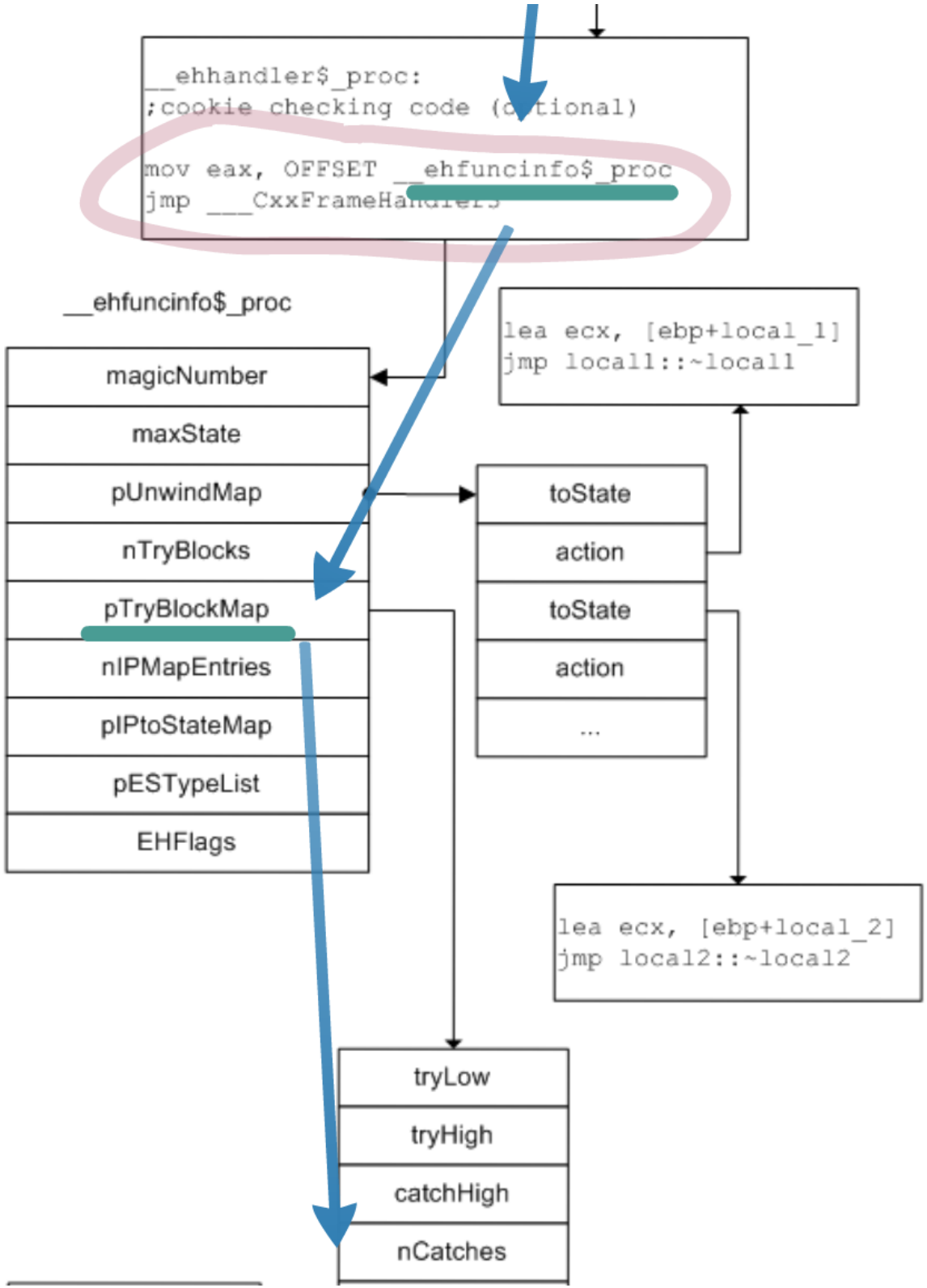
Thank you,
Igor & OpenRCE!

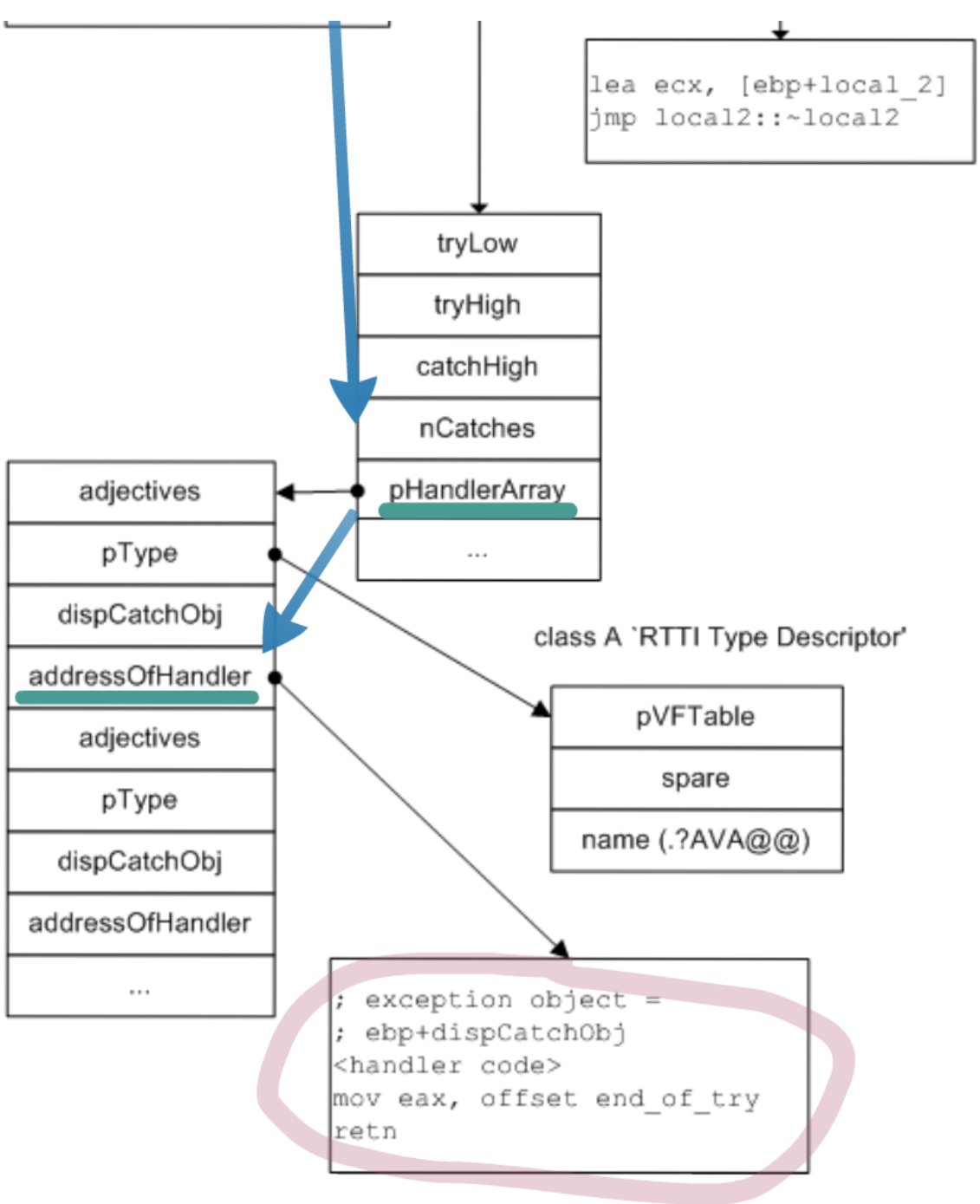


ou,

penRCE!


C++ EH Stack Layout
Nested Functions Stack
ESP
EH Cookie
Saved Registers
Local variables
GS Cookie
Saved ESP
EH Registration Node
Next SEH Frame
EH Handler
State
EBP
Saved EBP
Return Address
Function Arguments
__ehhandler$_proc:
;cookie checking code (optional)
mov eax, OFFSET __ehfuncinfo$_proc
jmp ___CxxFrameHandler3
__ehfuncinfo$_proc
lea ecx, [ebp+local_1]


__ehhandler$_proc:
;cookie checking code (optional)
mov eax, OFFSET __ehfuncinfo$_proc
jmp ___CxxFrameHandler3
__ehfuncinfo$_proc
magicNumber
maxState
pUnwindMap
nTryBlocks
pTryBlockMap
nIPMapEntries
pIPtoStateMap
pESTypeList
EHFlags
lea ecx, [ebp+local_1]
jmp local1::~local1
toState
action
toState
action
...
lea ecx, [ebp+local_2]
jmp local2::~local2
tryLow
tryHigh
catchHigh
nCatches


lea ecx, [ebp+local_2]
jmp local2::~local2
tryLow
tryHigh
catchHigh
nCatches
pHandlerArray
...
adjectives
pType
dispCatchObj
addressOfHandler
adjectives
pType
dispCatchObj
addressOfHandler
...
class A `RTTI Type Descriptor'
pVFTable
spare
name (.?AVA@@)
; exception object =
; ebp+dispCatchObj
<handler code>
mov eax, offset end_of_try
retn

In Practice: Back To The Bot

Registration Sequence

```
00401C83 push    0FFFFFFFFh
00401C85 push    offset _WinMain@16_SEH
00401C8A mov     eax, large fs:0
00401C90 push    eax
00401C91 mov     large fs:0, esp
```

```
00401D98 loc_401D98:
00401D98 mov     ecx, 69805h
00401D9D call    ecx
```

Exception

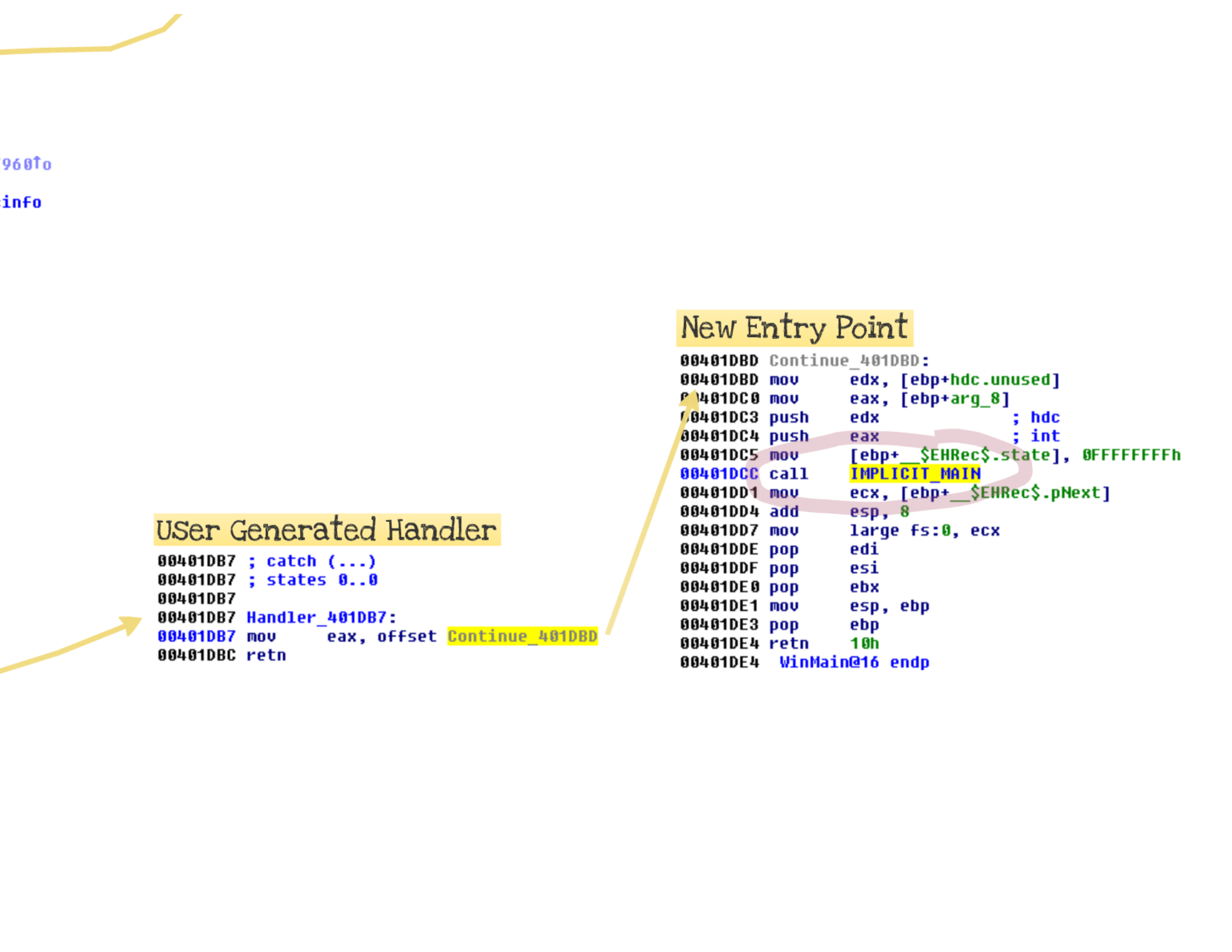
Compiler Generated Handler

```
00435080 ; Unwind handlers of 00401C80
00435080 ; Attributes: bp-based frame
00435080
00435080 _WinMain@16_SEH proc near
00435080 mov     eax, offset ehfuncinfo
00435085 jmp     __CxxFrameHandler
00435085 _WinMain@16_SEH endp
```

```
.rdata:0043AC90 ehfuncinfo dd 19930520h
.rdata:0043AC90
.rdata:0043AC90
.rdata:0043AC94 dd 2
.rdata:0043AC98 dd offset UnwindMap_43ACB0
.rdata:0043AC9C dd 1
.rdata:0043ACA0 dd offset TryBlockMap_43ACC0
.rdata:0043ACA4 dd 0
```

```
; DATA XREF: Stack[000006E0]:0012F960↑o
; _WinMain@16_SEH↑o
; magicNumber    ---- first ehfuncinfo
; maxState
; pUnwindMap
; nTryBlocks
; pTryBlockMap
; nIPMapEntries
```

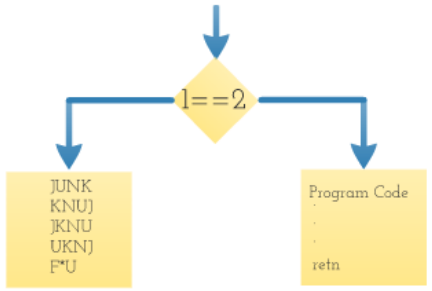
```
.rdata:0043AC90 ehfuncinfo dd 19930520h                 ; DATA XREF: Stack[000006E0]:0012F960↑o
.rdata:0043AC90                                         ; _WinMain@16_SEH↑o
.rdata:0043AC90                                         ; magicNumber    ---- first ehfuncinfo
.rdata:0043AC94 dd 2                                    ; maxState
.rdata:0043AC98 dd offset UnwindMap_43ACB0              ; pUnwindMap
.rdata:0043AC9C dd 1                                    ; nTryBlocks
.rdata:0043ACA0 dd offset TryBlockMap_43ACC0            ; pTryBlockMap
.rdata:0043ACA4 dd 0                                    ; nIPMapEntries
.rdata:0043ACA8 dd 0                                    ; pIPtoStateMap
.rdata:0043ACAC dd 0                                    ; pESTypeList
.rdata:0043ACB0 UnwindMap_43ACB0 dd 0FFFFFFFFh          ; DATA XREF: .rdata:0043AC98↑o
.rdata:0043ACB0                                         ; toState
.rdata:0043ACB4 dd 0                                    ; action
.rdata:0043ACB8 dd 0FFFFFFFFh                           ; toState
.rdata:0043ACBC dd 0                                    ; action
.rdata:0043ACC0 TryBlockMap_43ACC0 dd 0                 ; DATA XREF: .rdata:0043ACA0↑o
.rdata:0043ACC0                                         ; tryLow
.rdata:0043ACC4 dd 0                                    ; tryHigh
.rdata:0043ACC8 dd 1                                    ; catchHigh
.rdata:0043ACCC dd 1                                    ; nCatches
.rdata:0043ACD0 dd offset HandlerArray_43ACD8           ; pHandlerArray
.rdata:0043ACD4 dd 0
.rdata:0043ACD8 HandlerArray_43ACD8 dd 0                ; DATA XREF: .rdata:0043ACD0↑o
.rdata:0043ACD8                                         ; adjectives
.rdata:0043ACDC dd 0                                    ; pType    ---- 0 = any
.rdata:0043ACE0 dd 0                                    ; dispCatchObj
.rdata:0043ACE4 dd offset Handler_401DB7                ; addressOfHandler
```


960↑o
info
User Generated Handler
00401DB7 ; catch (...)
00401DB7 ; states 0..0
00401DB7
00401DB7 Handler_401DB7:
00401DB7 mov eax, offset Continue_401DBD
00401DBC retn
New Entry Point
00401DBD Continue_401DBD:
00401DBD mov edx, [ebp+hdc.unused]
00401DC0 mov eax, [ebp+arg_8]
00401DC3 push edx ; hdc
00401DC4 push eax ; int
00401DC5 mov [ebp+__$EHRec$.state], 0FFFFFFFFh
00401DCC call IMPLICIT_MAIN
00401DD1 mov ecx, [ebp+__$EHRec$.pNext]
00401DD4 add esp, 8
00401DD7 mov large fs:0, ecx
00401DDE pop edi
00401DDF pop esi
00401DE0 pop ebx
00401DE1 mov esp, ebp
00401DE3 pop ebp
00401DE4 retn 10h
00401DE4 WinMain@16 endp

Anti-Analysis

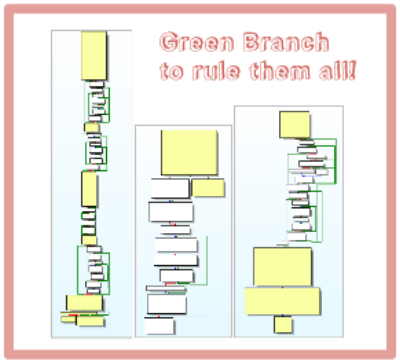
Trolls, Junk & Obfuscation

Opaque Predicates

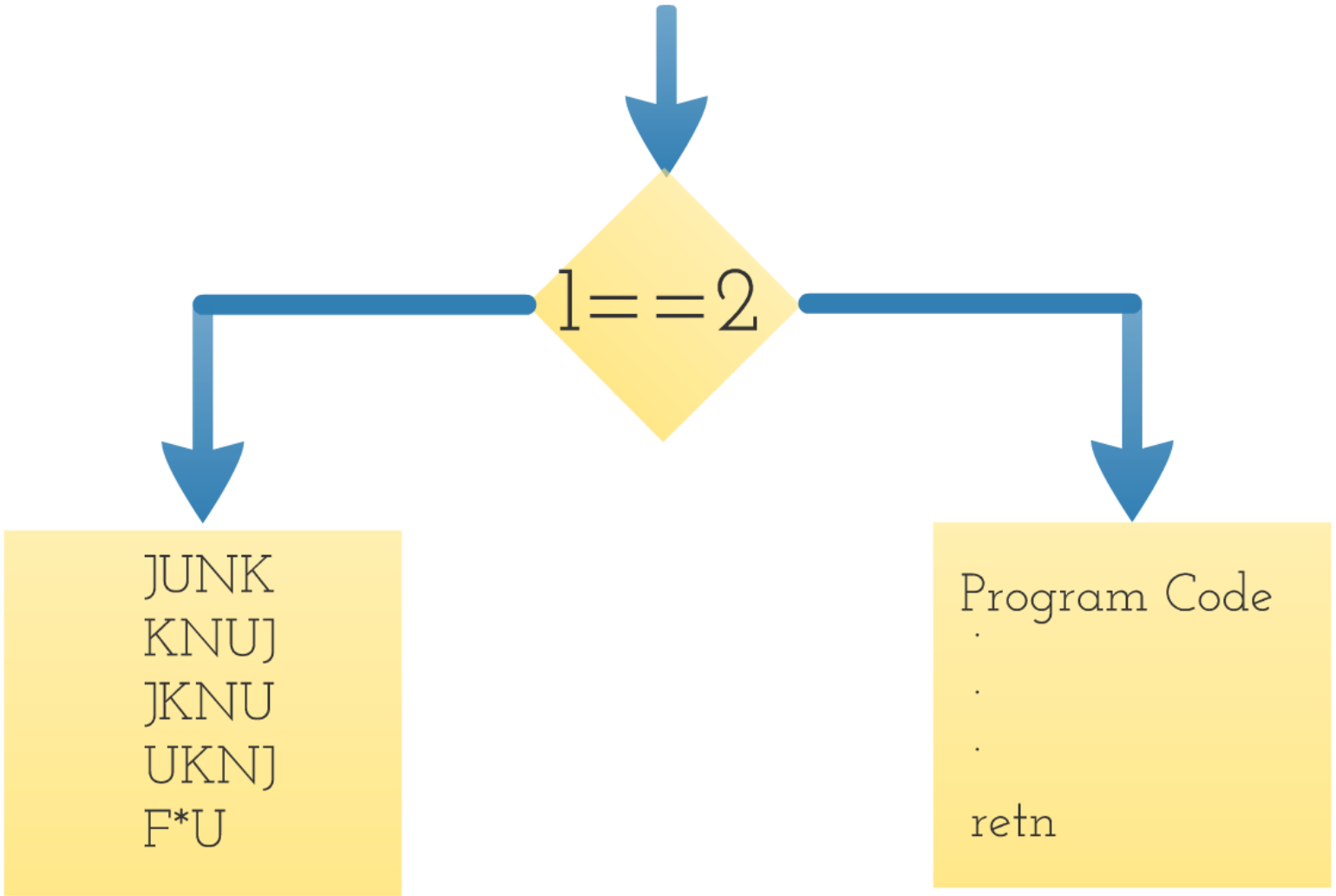


Slightly Obfuscated Opaque Predicates

```
text:004OF2E0 sub     esp, 7Ch
text:004OF2E3 mov     [esp+7Ch+var_78], ecx
text:004OF2E7 mov     dword ptr [ecx], offset off_4GE9B8
text:004OF2ED lea     eax, [esp+7Ch+var_78]
text:004OF2F1 lea     ecx, [esp+7Ch+var_78]
text:004OF2F5 imul    eax, ecx
text:004OF2F8 lea     edx, [esp+7Ch+var_78]
text:004OF2FC lea     ecx, [esp+7Ch+var_78]
text:004OF300 push    ebx
text:004OF301 sub     edx, ecx
text:004OF303 push    ebp
text:004OF304 push    esi
text:004OF305 cmp     edx, eax
text:004OF307 push    edi
text:004OF308 mov     [esp+8Ch+var_6A], 78h
text:004OF310 mov     [esp+8Ch+var_63], 47h
text:004OF312 jnz     short loc_40F350
```



Opaque Predicates

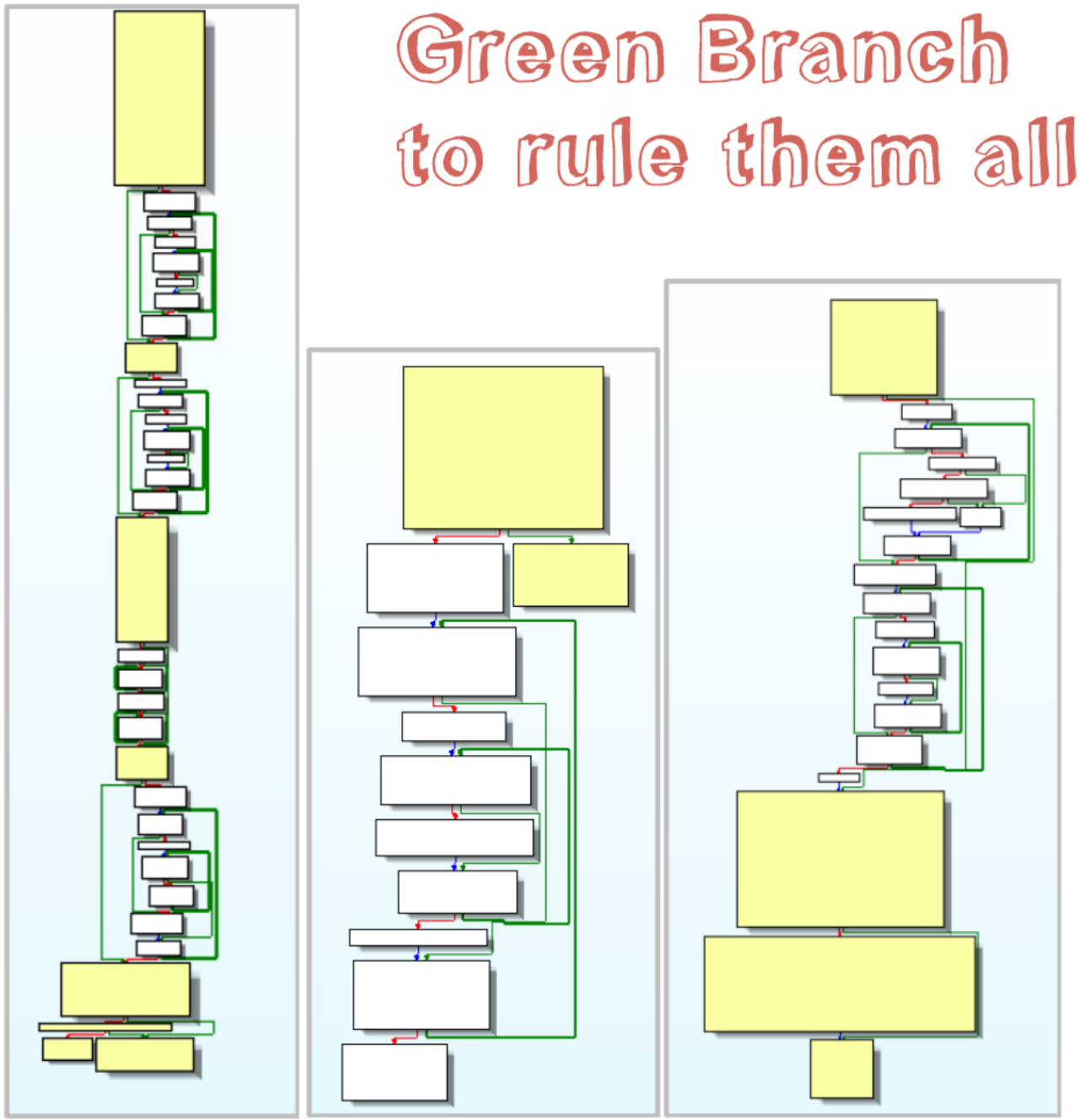


Slightly Obfuscated Opaque Predicates

```
0040F2E0 sub     esp, 7Ch
0040F2E3 mov     [esp+7Ch+var_78], ecx
0040F2E7 mov     dword ptr [ecx], offset off_4370A4
0040F2ED lea     eax, [esp+7Ch+var_78]
0040F2F1 lea     ecx, [esp+7Ch+var_78]
0040F2F5 imul    eax, ecx
0040F2F8 lea     edx, [esp+7Ch+var_78]
0040F2FC lea     ecx, [esp+7Ch+var_78]
0040F300 push    ebx
0040F301 sub     edx, ecx
0040F303 push    ebp
0040F304 push    esi
0040F305 cmp     edx, eax
0040F307 push    edi
0040F308 mov     [esp+8Ch+var_64], 7Bh
0040F30D mov     [esp+8Ch+var_63], 41h
0040F312 jnz     short loc_40F35A
```

```
.text:0040F2E3  mov   [esp+7Ch+var_78], ecx
.text:0040F2ED  lea   eax, [esp+7Ch+var_78]
.text:0040F2F1  lea   ecx, [esp+7Ch+var_78]
.text:0040F2F5  imul  eax, ecx
.text:0040F2F8  lea   edx, [esp+7Ch+var_78]
.text:0040F2FC  lea   ecx, [esp+7Ch+var_78]
.text:0040F301  sub   edx, ecx
.text:0040F305  cmp   edx, eax
.text:0040F312  jnz   short loc_40F35A
```

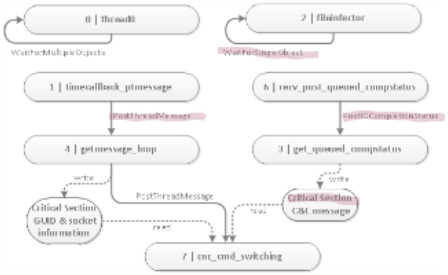
Green Branch to rule them all!



Analysts' Headaches

Headache
The Magic Multi-Threaded Labyrinth

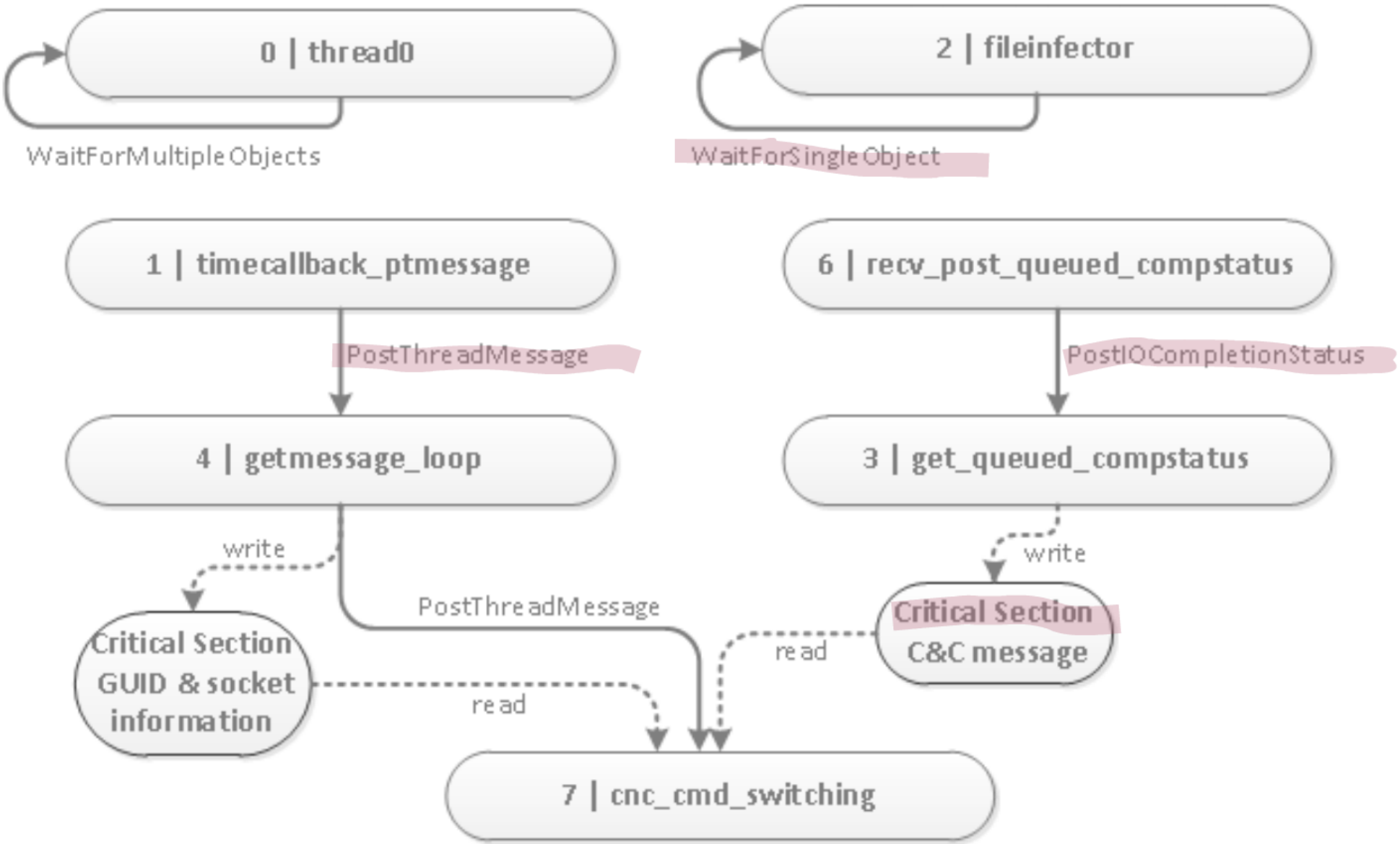
Bot Internals



How To Get There

1. Realize there are multiple threads that you have to follow
2. Spot inter-thread communication & synchronization
3. Analyze function bodies with significant functionality
4. Bring down what information is exchanged between threads and how one thread influences the other

Bot Internals



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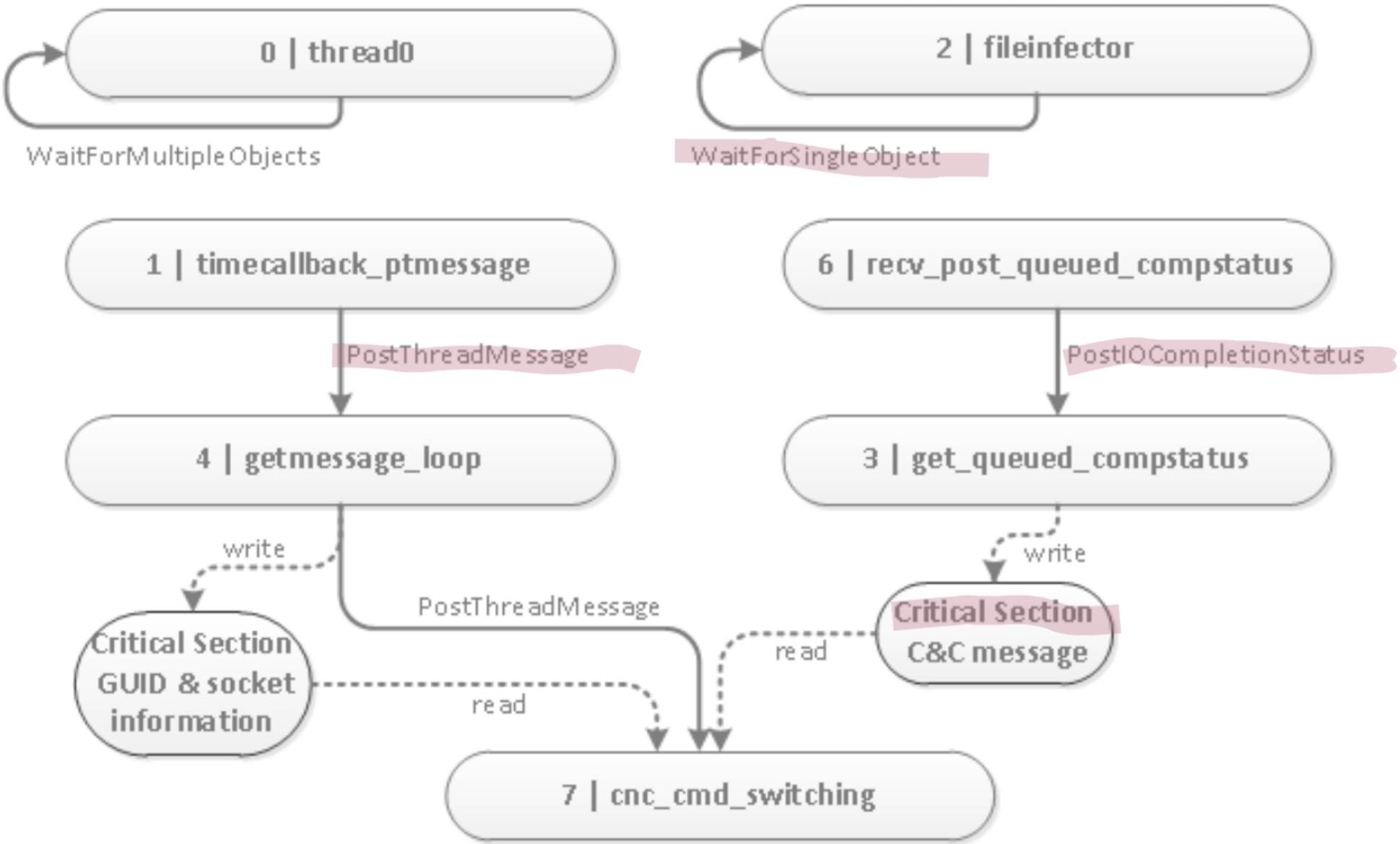
Bot Internals



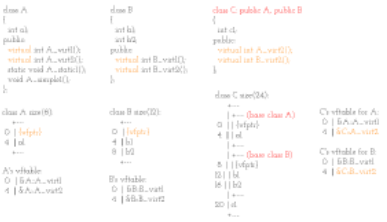
Headache

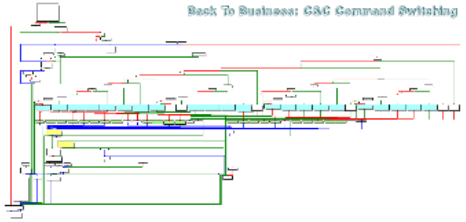
Into The Unknown with C++

C++

- Multiple inheritance
- Indirect calls
- Binary overhead for "glue code"
- Non-linear code
- Few documentation for reversers

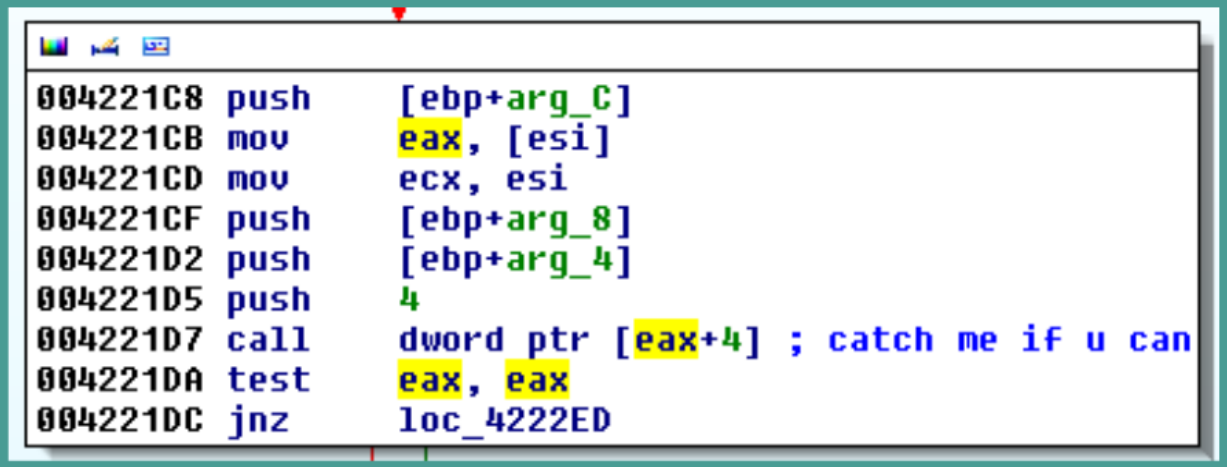
Special thanks to Igor Skochinski & OpenRCE





C++

Multiple inheritance
Indirect calls
Binary overhead for "glue code"
Non-linear code
Few documentation for reversers



```
004221C8 push    [ebp+arg_C]
004221CB mov     eax, [esi]
004221CD mov     ecx, esi
004221CF push    [ebp+arg_8]
004221D2 push    [ebp+arg_4]
004221D5 push    4
004221D7 call    dword ptr [eax+4] ; catch me if u can
004221DA test    eax, eax
004221DC jnz     loc_4222ED
```

Special thanks to Igor Skochinski & OpenRCE

```
class A
{
  int a1;
public:
  virtual int A_virt1();
  virtual int A_virt2();
  static void A_static1();
  void A_simple1();
};
```

```
class A size(8):
    +---
 0  | {vfptr}
 4  | a1
    +---

A's vftable:
 0  | &A::A_virt1
 4  | &A::A_virt2
```

```
class B
{
  int b1;
  int b2;
public:
  virtual int B_virt1();
  virtual int B_virt2();
};
```

```
class B size(12):
    +---
 0  | {vfptr}
 4  | b1
 8  | b2
    +---

B's vftable:
 0  | &B::B_virt1
 4  | &B::B_virt2
```

```
class C: public A, public B
{
  int c1;
public:
  virtual int A_virt2();
  virtual int B_virt2();
};
```

```
class C size(24):
        +---
        | +--- (base class A)
 0      | | {vfptr}
 4      | | a1
        | +---
        | +--- (base class B)
 8      | | {vfptr}
12      | | b1
16      | | b2
        | +---
20      | c1
        +---

C's vf
 0  |
 4  | &

C's vf
 0  |
 4  | &
```

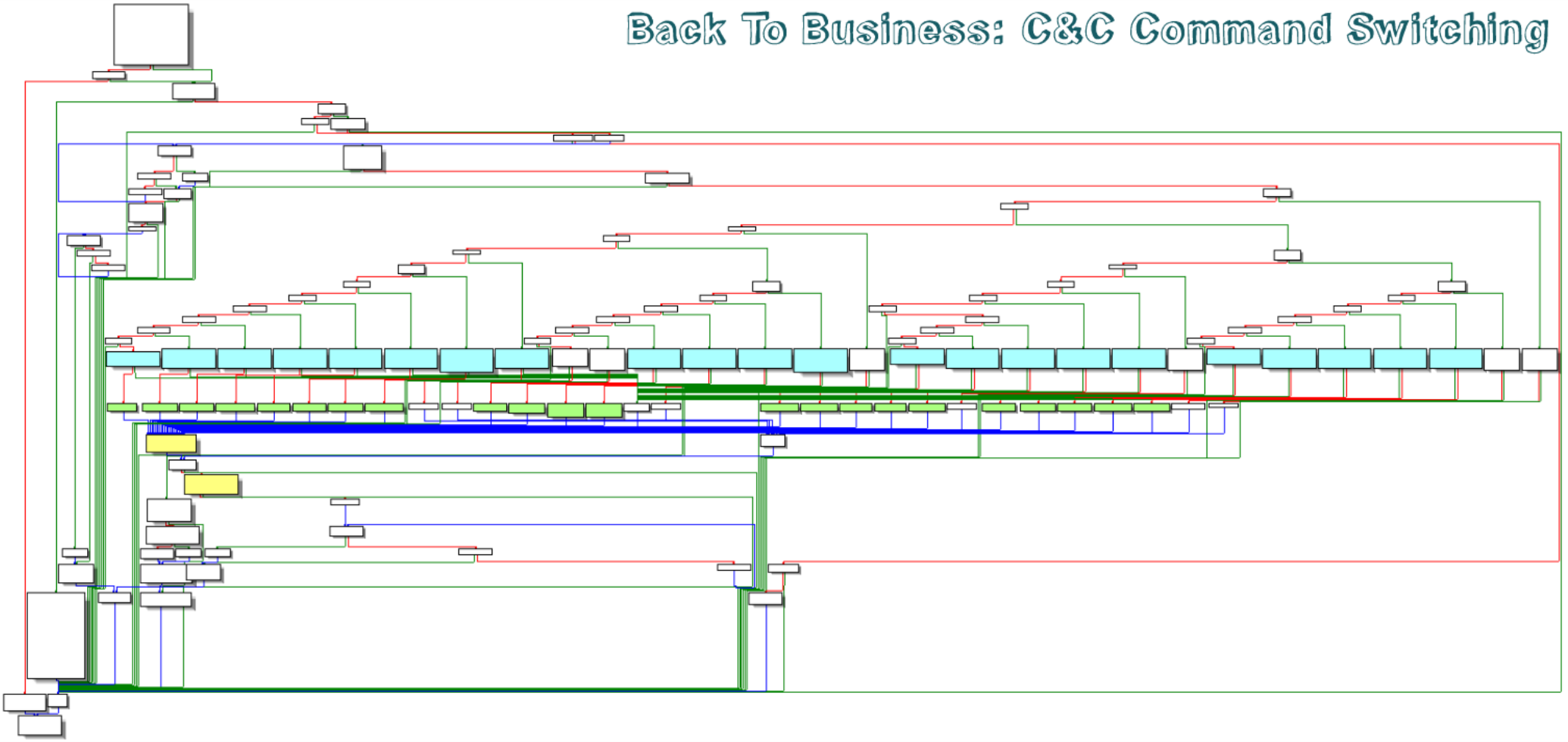
```
class B
{
  int b1;
  int b2;
public:
  virtual int B_virt1();
  virtual int B_virt2();
};
```

```
class C: public A, public B
{
  int c1;
public:
  virtual int A_virt2();
  virtual int B_virt2();
};
```

```
class B size(12):
    +---
 0  | {vfptr}
 4  | b1
 8  | b2
    +---

B's vftable:
 0  | &B::B_virt1
 4  | &B::B_virt2
```

```
class C size(24):
      +---
      | +--- (base class A)
 0    | | {vfptr}
 4    | | a1
      | +---
      | +--- (base class B)
 8    | | {vfptr}
12    | | b1
16    | | b2
      | +---
20    | c1
      +---

C's vftable for A:
 0  | &A::A_virt1
 4  | &C::A_virt2

C's vftable for B:
 0  | &B::B_virt1
 4  | &C::B_virt2
```

Back To Business: C&C Command Switching



Command: move_file

Memory Allocation

```
00421CD9 push    edx             ; unsigned int
00421CDA call    ??2@YAPAXI@Z    ; operator new(uint)
00421CDF pop     ecx
00421CE0 mov     [ebp+arg_10], eax
00421CE3 test    eax, eax
00421CE5 mov     [ebp+__$EHRec$.state], 0Ah
00421CEC jz      loc_42210F
```

Instantiation

```
00421CF2 mov     ecx, eax
00421CF4 call    ctor_movefile
00421CF9 jmp     loc_422111
```

Constructor

```
004297A2 ctor_movefile proc near
004297A2 push    esi
004297A3 mov     esi, ecx
004297A5 call    ctor_command_bas
004297AA mov     dword ptr [esi],
004297B0 mov     eax, esi
004297B2 pop     esi
004297B3 retn
004297B3 ctor_movefile endp
```

```
.rdata:00437584 vftable_movefile
.rdata:00437584
.rdata:00437588 dd offset move_fi
```

```
;
tate], 0Ah
```

Constructor

```
004297A2 ctor_movefile proc near
004297A2 push    esi
004297A3 mov     esi, ecx
004297A5 call    ctor_command_baseclass
004297AA mov     dword ptr [esi], offset vftable_movefile
004297B0 mov     eax, esi
004297B2 pop     esi
004297B3 retn
004297B3 ctor_movefile endp
```

```
.rdata:00437584 vftable_movefile dd offset dtor_movefile
.rdata:00437584
.rdata:00437588 dd offset move_file
.rdata:0043758C dd offset set_eax_null
```

n Call

```
; catch me if u can
```

xrefs to ctor_command_baseclass

Direction	Type	Address	Text
Up	p	sub_424F34+3	call ctor_command_baseclass
Up	p	sub_4253FE+3	call ctor_command_baseclass
Up	p	sub_42556C+3	call ctor_command_baseclass
Up	p	sub_4259BD+3	call ctor_command_baseclass
Up	p	sub_425CD9+3	call ctor_command_baseclass
Up	p	sub_425F87+11	call ctor_command_baseclass
Up	p	sub_426AA1+3	call ctor_command_baseclass
Up	p	sub_426DB1+3	call ctor_command_baseclass
Up	p	sub_4270C5+3	call ctor_command_baseclass
Up	p	sub_42742D+18	call ctor_command_baseclass
Up	p	sub_427B6F+3	call ctor_command_baseclass
Up	p	sub_427CE9+3	call ctor_command_baseclass
Up	p	sub_427E35+3	call ctor_command_baseclass
Up	p	sub_427F3A+3	call ctor_command_baseclass
Up	p	sub_4285C1+3	call ctor_command_baseclass
Up	p	sub_4287FB+3	call ctor_command_baseclass
Up	p	sub_428A58+3	call ctor_command_baseclass
Up	p	sub_428F53+3	call ctor_command_baseclass
Up	p	sub_429301+3	call ctor_command_baseclass
Up	p	sub_429453+3	call ctor_command_baseclass
Up	p	sub_4295C0+3	call ctor_command_baseclass
Up	p	ctor_movefile+3	call ctor_command_baseclass
Up	p	sub_429984+15	call ctor_command_baseclass

23 commands,
23 cross references

```
or
roc near

x
mmand_baseclass
tr [esi], offset vftable_movefile
i


ndp


movefile dd offset dtor_movefile

t move_file
t set_eax_null
```

Base Class Constructor

```
00429B75 ctor_command_baseclass proc near
00429B75 mov     eax, ecx
00429B77 mov     dword ptr [eax], offset vftable_cmdbase
00429B7D retn
00429B7D ctor_command_baseclass endp
```

```
.rdata:004375A0 vftable_cmdbase dd offset dtor_cmd_baseclass
.rdata:004375A0                                         ; DAT
.rdata:004375A0                                         ; vft
.rdata:004375A4 dd offset _purecall
.rdata:004375A8 dd offset _purecall
```

Memory Allocation

```
00421CD9 push    edx             ; unsigned int
00421CDA call    ??2@YAPAXI@Z    ; operator new(uint)
00421CDF pop     ecx
00421CE0 mov     [ebp+arg_10], eax
00421CE3 test    eax, eax
00421CE5 mov     [ebp+__$EHRec$.state], 0Ah
00421CEC jz      loc_42210F
```

Instantiation

```
00421CF2 mov     ecx, eax
00421CF4 call    ctor_movefile
00421CF9 jmp     loc_422111
```

Constructor

```
004297A2 ctor_movefile proc near
004297A2 push    esi
004297A3 mov     esi, ecx
004297A5 call    ctor_command_baseclass
004297AA mov     dword ptr [esi], offset
004297B0 mov     eax, esi
004297B2 pop     esi
004297B3 retn
004297B3 ctor_movefile endp
```

```
.rdata:00437584 vftable_movefile dd offs
.rdata:00437584
.rdata:00437588 dd offset move_file
.rdata:0043758C dd offset set_eax_null
```

Virtual Function Call

```
004221C8 push    [ebp+arg_C]
004221CB mov     eax, [esi]
004221CD mov     ecx, esi
004221CF push    [ebp+arg_8]
004221D2 push    [ebp+arg_4]
004221D5 push    4
004221D7 call    dword ptr [eax+4] ; catch me if u can
004221DA test    eax, eax
004221DC jnz     loc_4222ED
```

Fairy Tale's Happy Ending

Control self_terminate system_shutdown shell_execute

Multimedia gdi_capture_window gdi_screenshot

File System list_directory rename_files delete_files copy_files

Desinfection check_fingerprint

Control

self_terminate system_shutdown
shell_execute

Multimedia

gdi_capture_window
gdi_screenshot

File System

list_directory rename_files
copy_files
delete_files

Desinfection

check_fingerprint

DIY Links

Thomas Dulliens Blog & The Malware
http://addxorrol.blogspot.co.at

Igor Skochinski
http://www.hexblog.com/wp-content/uploads/2012/06/Recon-2012-Skochinsky-Compiler-Internals.pdf
http://www.openrce.org/articles/full_view/21
http://www.openrce.org/articles/full_view/23

Matt Pietrek
http://www.microsoft.com/msj/0197/Exception/Exception.aspx

Mark Yason & Paul Sabanal
http://www.blackhat.com/presentations/bh-dc-07/Sabanal_Yason/Paper/bh-dc-07-Sabanal_Yason-WP.pdf

Vishal Kochhar
http://www.codeproject.com/Articles/2126/How-a-C-compiler-implements-exception-handling?display=Print

Selvam
http://www.codeproject.com/Articles/7953/Thread-Synchronization-for-Beginners

Josh Haberman
http://blog.reverberate.org/2013/05/deep-wizardry-stack-unwinding.html

Ilfak Guilfanov
http://www.hexblog.com/?p=19