Exploit Wednesdays

AN OVERVIEW OF BINARY PATCH ANALYSIS

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Overview

- Who I am
- How I got into security
- Hacking video games
- Binary diffing
- Questions

whoami

- Security consultant @ Cigital
- Security researcher previously
- Student of life (always learning)
- Husband
- Music lover
  - Mostly techno: DnB, Trance, and EDM
- Video game player/hacker

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Who likes video games?

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How I Got Into Security

- Video games: they're fun, but difficult
- There are 2 solutions to this problem:
  1. Practice to eventually get better
  2. Cheat (hack) to get way better right now
- Too lazy/impatient to practice, so I learned how to hack

Hacking Games: Demo

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Hacking Games

- Example Goals
  - Get unlimited health
  - Gain access to restricted parts of the game:
    - See hidden parts of a map
    - Access powers that are above current level
- What other types of hacks would you want to use in a game?

Hacking Games: General Approach

- Modify the game to reach your goal
  - While the game is running (dynamic)
  - Before it is launched/on disk (static)
- Overall process:
  - Find out how the game stores/manipulates data of interest (e.g.: current health value)
  - Change how the game stores/manipulates that data (e.g.: don’t reduce health value)

Hacking Games: Process Review

- Think like an attacker
- Have a goal-based approach
- Have the skills to reach those goals
  - Learn the skills, if needed
- Be creative with the techniques used
- Have fun with it!

Hacking Games: Skills Required

- Reverse engineering/dynamic analysis
  - Find target values in memory
  - Identify code of interest
  - Understand how the code works
  - Modify code flow to suit our needs
- These same skills are used in the security industry every day

How does this apply to the industry?

- The skills needed to hack games are generally required in the following fields:
  - digital forensics
  - malware analysis
  - **vulnerability research**
  - offensive security research (writing exploits)
  - embedded systems analysis
  - mobile research
  - and many more

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Vulnerability Research

- Lots of different types of vulnerability research (the following is just a start):
  - Vulnerability discovery
    - Fuzzing (finds bugs)
    - Analysis of design specifications (finds flaws)
  - **Vulnerability (re)discovery: binary diffing**
  - Exploit development
    - Development of proof of concept code
    - Development of weaponized exploits

Binary Diffing

- Binary diffing (aka: bindiffing) is a method used to analyze the changes that are introduced by patches
- Helps identify exactly what code was fixed in a patch
- Required because patch descriptions from vendors are often intentionally very vague

Binary Diffing: Purpose

- Vulnerabilities that are identified can be used to create:
  - Proof of concepts (aka: PoCs): something that triggers the vulnerability
  - Exploits based on the PoCs
  - Behavioral-based exploit-detection signatures (based on the calls involved when triggering the vulnerability)

Binary Diffing: What is it?

- Binary diffing takes two compiled files:
  - Original file: Before a patch is applied
  - Patched file: After a patch is applied
- These two files are compared to find what exactly was patched
- This is very useful for analyzing security patches, such as those released on Microsoft's Patch Tuesday

Binary Diffing: Exploit Wednesday

- Patch Tuesday occurs on the second Tuesday of every month
- Attackers analyze these patches using bindiffing techniques and develop exploits
- Sometimes happens within a day
- Patch Tuesday + 1 day = “Exploit Wednesday”

Are there any questions so far?

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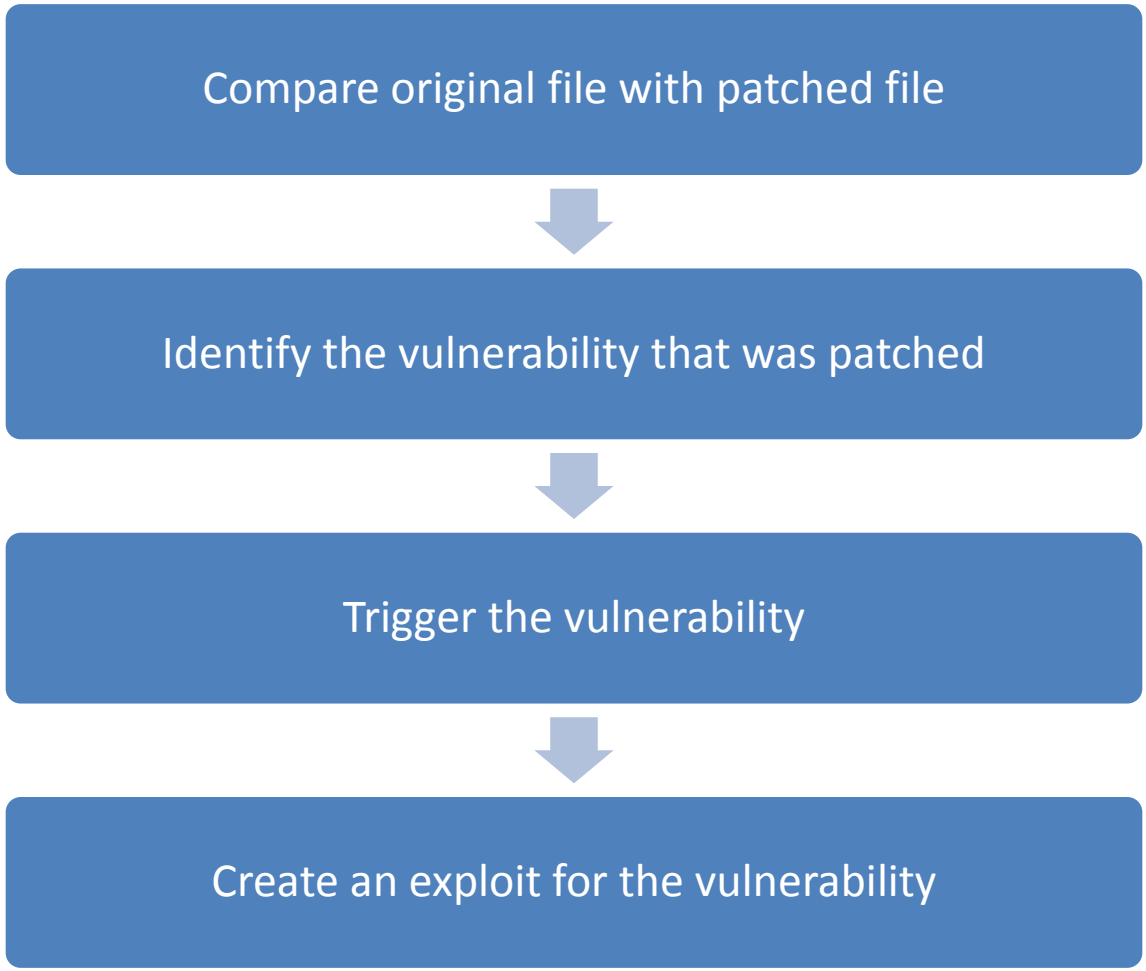
Binary Diffing: Overview



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Binary Diffing: A Simple Example

```
push    dword ptr [esi] ; void *
call    ??3@YAXPAX@Z    ; operator delete(void *)
pop     ecx
```


```
push    dword ptr [esi] ; void *
call    ??3@YAXPAX@Z    ; operator delete(void *)
pop     ecx
mov     [esi], ebx
```


Binary Diffing: A Simple Example (cont.)

```
push    dword ptr [esi] ; void *
call    ??3@YAXPAX@Z    ; operator delete(void *)
pop     ecx
mov     [esi], ebx
```

- The added instruction is used to clear out the value of [ESI] (ebx = 0)
- Translation:
  - Before the patch, a pointer was not properly cleared out (it was not properly set to 0)
  - The patch fixed this

Binary Diffing: A Simple Example (cont.)

- That patch was for CVE-2014-0301
- Description from cve.mitre.org:
  - “Double free vulnerability in qedit.dll in DirectShow in Microsoft Windows... allows remote attackers to execute arbitrary code via a crafted JPEG image”
- Translation: a user views my maliciously crafted picture and I can run code on their computer

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Exploited!

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Binary Diffing: General Process

- How to find the patched code of interest:
  - Get the old and new versions of the file
  - Diff the files
  - Sort through the noise to find the real issue
- There are practical ways to do this and there are less practical ways

Try to think of some ways to compare two binary files. What approaches come to mind?

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Binary Diffing: Less Practical Approach #1

- Doing a byte by byte analysis of the code
- This will make about as much sense as trying to parse this picture without a computer and/or calculator

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Binary Diffing: Less Practical Approach #1 (cont.)

- Byte-by-byte comparison is not useful as a generic approach
- On the x86 architecture (and others), there are variable-length instructions
- X86: 1 instruction can be up to 14 bytes
- Swapping sequential, semantically separate instructions can cause up to 28 bytes of change

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Binary Diffing: Less Practical Approach #1 (cont.)

- Consider the example from earlier
- The byte changes of the instructions are:
  - Original: `14684D70 FF 36 E8 11 D0 FD FF 59`
  - Patched: `14684D5F FF 36 E8 12 D0 FD FF 59 89 1E`
- Problem areas:
  - Shared instructions show variation
    - `11` becomes `12`
  - The addresses are completely different
    - Address ended in `70`, but now ends in `5F`

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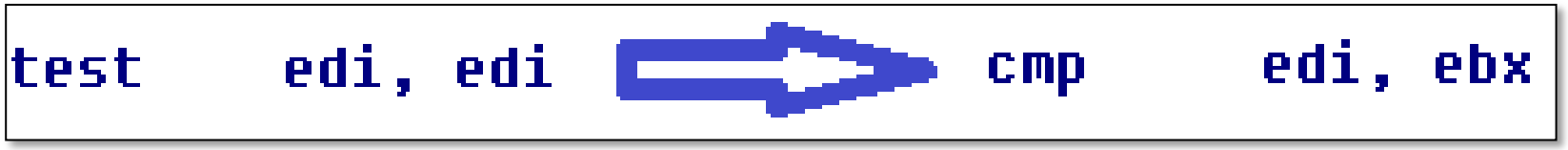
Binary Diffing: Less Practical Approach #2

- Disassemble all the code from the before/after files and do a source code comparison of the disassembled code
- Possible, but not always practical
- Generates lots of noise, due to structural changes
- This becomes a search for a needle in a haystack

Binary Diffing: Noise



- Noise is usually introduced in a patch
  - Compiler option change (e.g. optimization flags)
  - Feature updates
  - Modification of the compiler itself
  - Refactoring
  - Code cleanup

Binary Diffing: Practical Approach #1

- Use tools
  - DarunGrim (free)
  - BinDiff ($$$)
- Both require IDA Pro ($$$)
  - Interactive DisAssembler
- This all costs $$$, but if you work in the industry, your employer will pay for it

DarunGrim

zynamics BinDiff

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Binary Diffing: Practical Approach #2

- Write your own disassembler by using freely available disassembler libraries
  - BeaEngine (LGPL 3) 
  - diStorm (GPL 3) 
- I started to do this and then realized why commercial products like IDA exist
- Automatic file disassembly is **really hard**
  - Lots of difficulties surrounding file structure
    - PE files / ELF / Mach-O

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Binary Diffing: Academic World vs Industry

- Academic world
  - There are more opportunities to spend time inventing a better wheel
- Security industry
  - Results are needed sooner rather than later
  - It is more cost effective to use existing tools that might not be perfect, but get the job done faster in the short term
- Note: there are always exceptions

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Binary Diffing: Tools

- Highlight changes, additions, and removals of instructions
- Can usually be used to jump to the relevant code within IDA
- Are sometimes extensible
  - Allows for writing plugins
  - Can also create external standalone applications that use the core of the tools

Binary Diffing: Tool-Specific Advantages

- DarunGrim advantages
  - Provides a “security implication score”
    - Helps separate security vs regular patches
  - Open source (free!)
- BinDiff advantages
  - Synchronizes original/patched views
  - Allows filtering by change type:
    - Structural changes
    - Instructions changed

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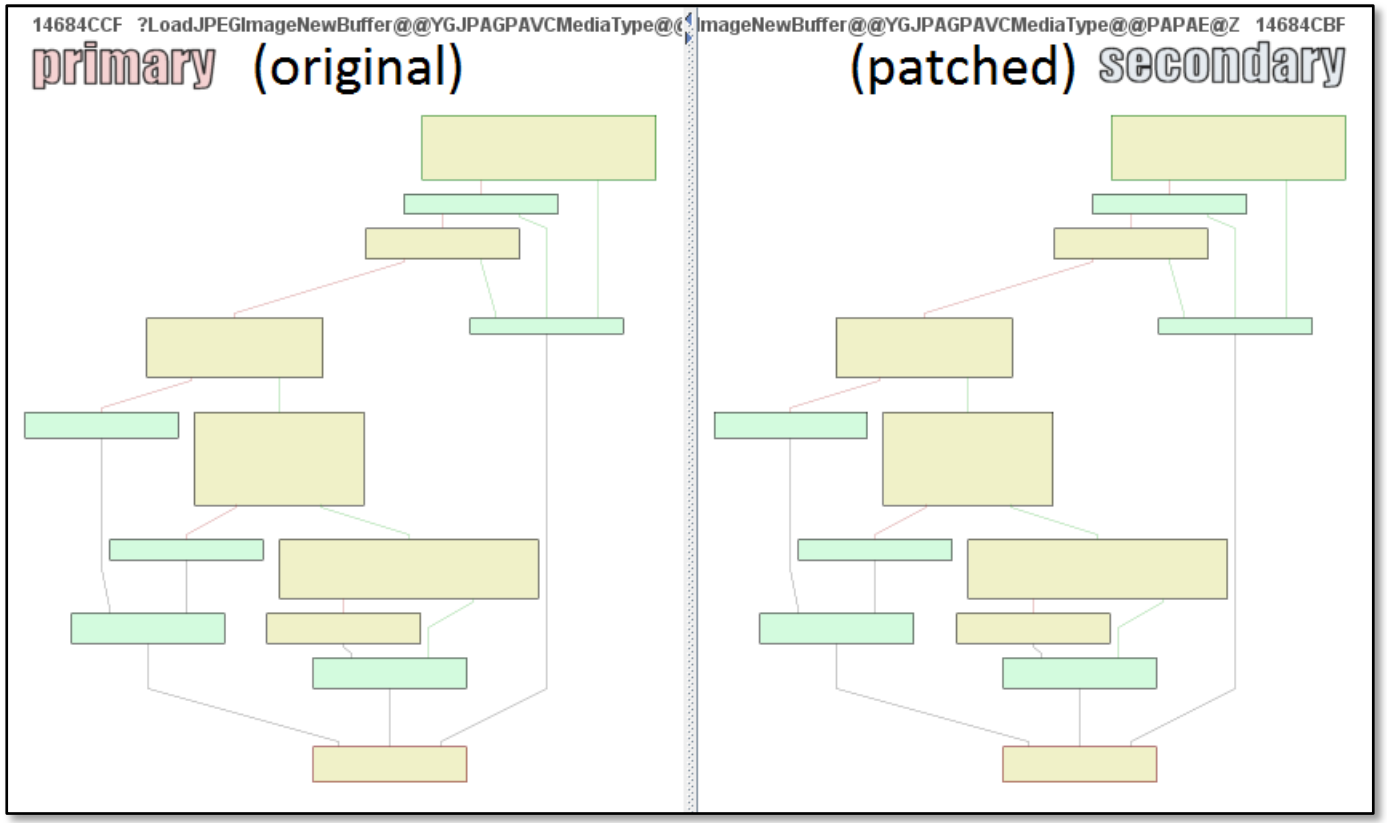
Binary Diffing: BinDiff Changes At-A-Glance

- View changes to functions at a glance



Binary Diffing: DarunGrim Advantages

- Compare original and the patched files
- Look at the security implication score
- Start with the highest score and move down the list

Patched	Security Implication Score
?LoadJPEGImageNewBuffer@@YGJPAGPAVCMediaType@@PAPAE@Z	6
?OpenTGAFile@@YGJPAXPAPAEPAVCMediaType@@PAE@Z	2
?NonDelegatingQueryInterface@CBasePin@@UAGJABU_GUID@@PAPAX@Z	1

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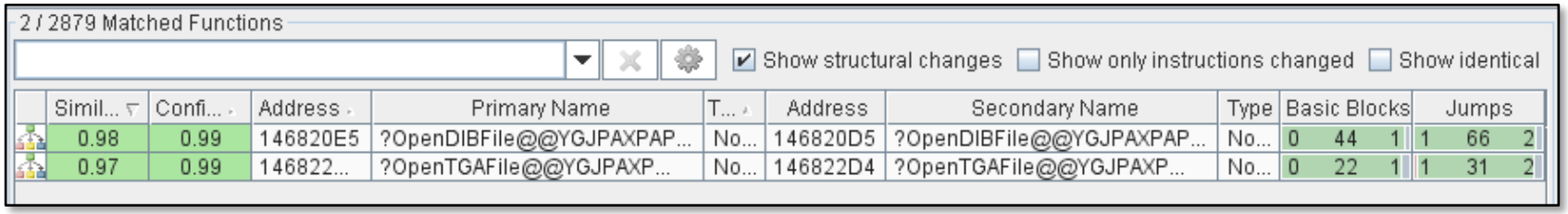
Binary Diffing: BinDiff Advantages

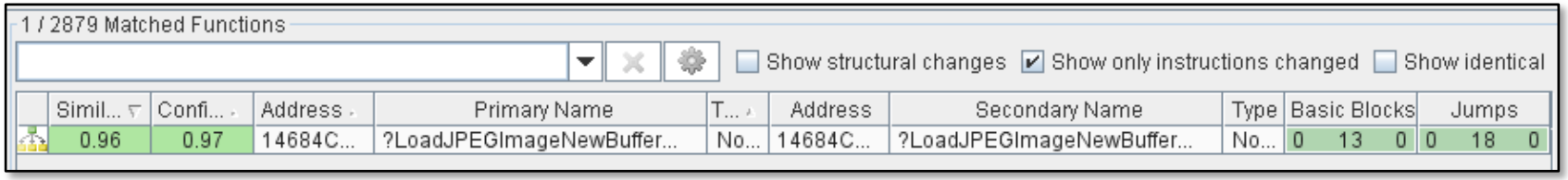
- Filter results based on change properties
- View structural changes


2 / 2879 Matched Functions

Show structural changes | Show only instructions changed | Show identical

	Simil...	Confi...	Address	Primary Name	T...	Address	Secondary Name	Type	Basic Blocks	Jumps
	0.98	0.99	146820E5	?OpenDIBFile@@YGJPAXPAP...	No...	146820D5	?OpenDIBFile@@YGJPAXPAP...	No...	0 44 1	1 66 2
	0.97	0.99	146822...	?OpenTGAFile@@YGJPAXP...	No...	146822D4	?OpenTGAFile@@YGJPAXP...	No...	0 22 1	1 31 2

- View changes to instructions


1 / 2879 Matched Functions

Show structural changes | Show only instructions changed | Show identical

	Simil...	Confi...	Address	Primary Name	T...	Address	Secondary Name	Type	Basic Blocks	Jumps
	0.96	0.97	14684C...	?LoadJPEGImageNewBuffer...	No...	14684C...	?LoadJPEGImageNewBuffer...	No...	0 13 0	0 18 0

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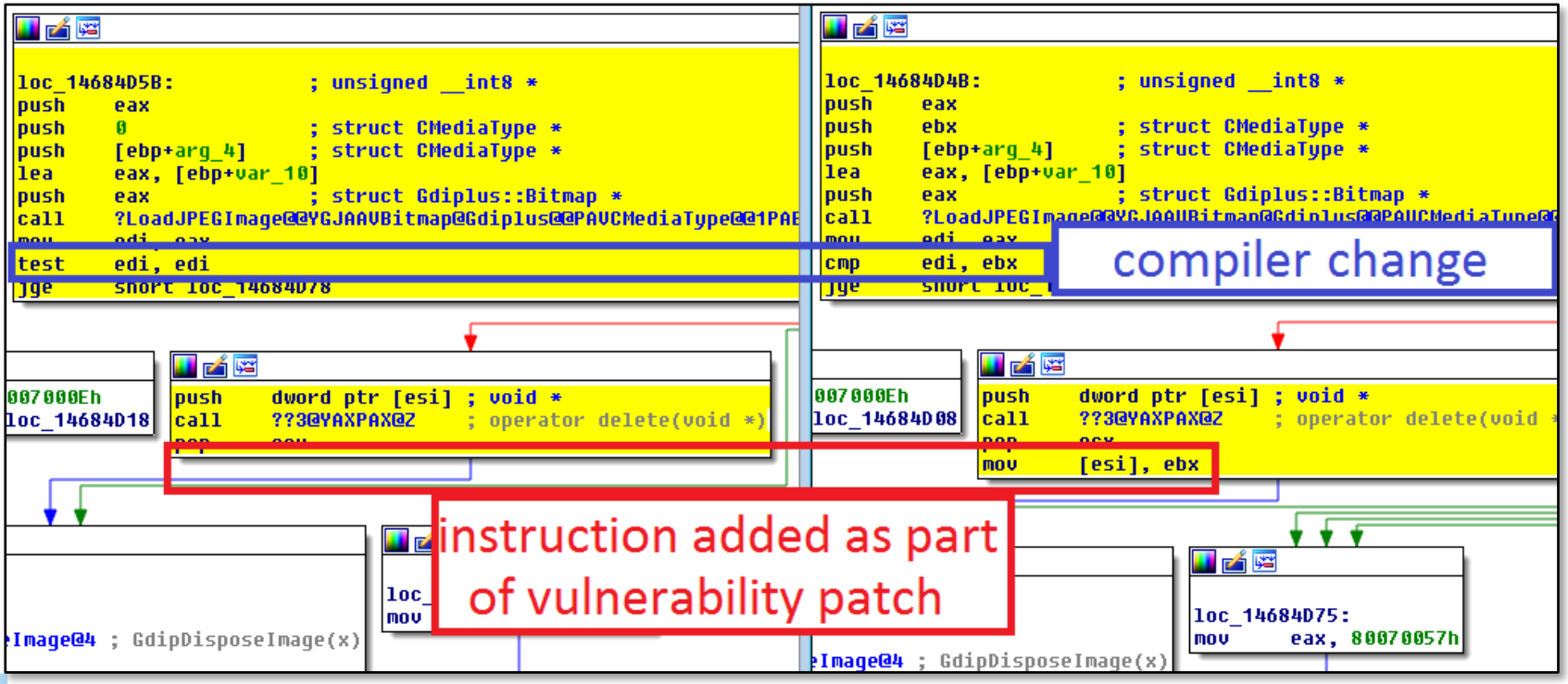
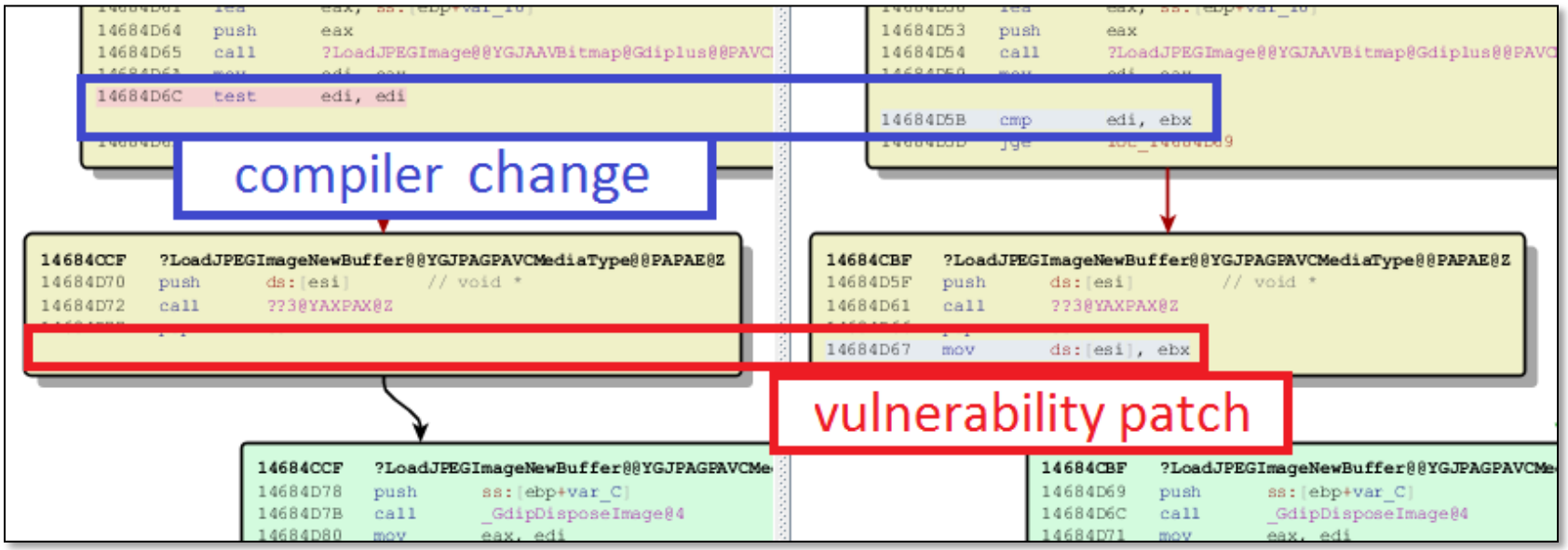
Binary Diffing: DarunGrim Code Comparison

- Instruction-group changes shown in IDA
  - Identify compiler changes vs security patch



Binary Diffing: BinDiff Code Comparison

- BinDiff can show changes without viewing them in IDA Pro
- Shows instruction-level differences



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Binary Diffing: Found the Vulnerability

```
push    dword ptr [esi] ; void *
call    ??3@YAXPAX@Z    ; operator delete(void *)
pop     ecx
```

```
push    dword ptr [esi] ; void *
call    ??3@YAXPAX@Z    ; operator delete(void *)
pop     ecx
mov     [esi], ebx
```

```
14684CCF    ?LoadJPEGImageNewBuffer@@YGJPAGPAVCMediaType@@PAPAE@Z
14684D70    push    ds:[esi]        // void *
14684D72    call    ??3@YAXPAX@Z
14684D77    pop     ecx
```

```
14684CBF    ?LoadJPEGImageNewBuffer@@YGJPAGPAVCMediaType@@PAPAE@Z
14684D5F    push    ds:[esi]        // void *
14684D61    call    ??3@YAXPAX@Z
14684D66    pop     ecx
14684D67    mov     ds:[esi], ebx
```

- The patch has been identified
- Now what?

Proof of concept creation: How do you go about making a proof of concept that will trigger the vulnerability?

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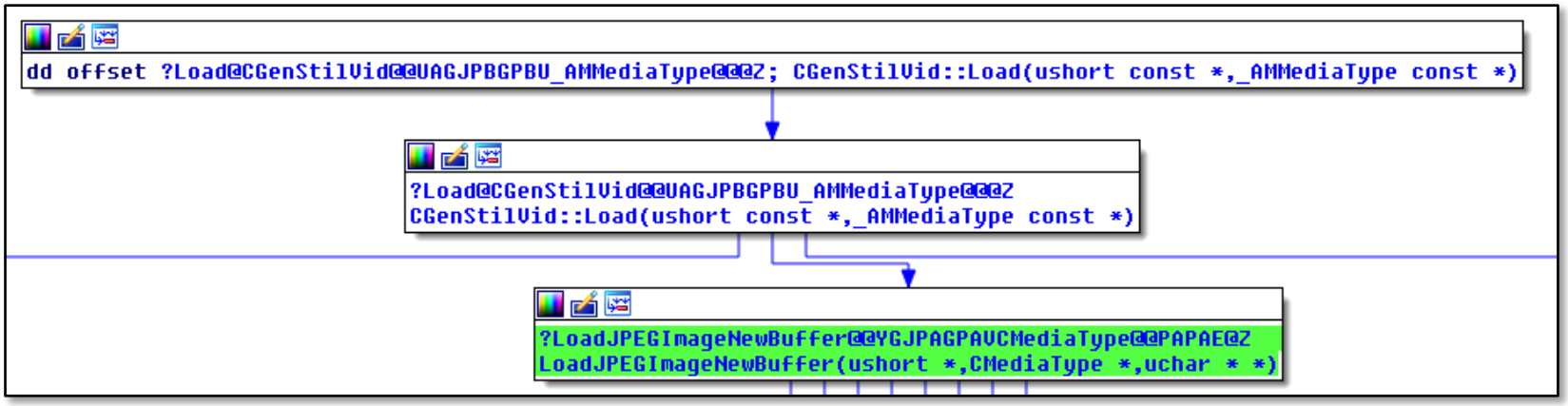
Binary Diffing: Triggering the Vulnerability

- Find out how to call the vulnerable function
- Use IDA Pro to find a callable API



- Look at (or near) the root function

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Binary Diffing: Triggering the Vulnerability (cont.)

- If a callable API is found:
  - Craft the API call's arguments carefully in order to trigger the vulnerable condition
- If no callable API is found:
  - Look up the chain of calls, looking for hints as to how to reach the vulnerable condition
- Make a proof of concept file, network packet, API call, etc.

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Binary Diffing: Triggering the Vulnerability (cont.)

- Find lots of samples online
- Set breakpoints in and around the target function
- Run through all the samples to see which ones (if any) come near or actually hit the vulnerable function
- Modify the successful samples to focus in on and trigger the vulnerable code

Binary Diffing: Create a Proof-of-Concept

- Know how to trigger the vulnerability
- Create a simplified PoC
  - Can skip this step if no sample was used to trigger the vulnerability
- Make it **very** easy to use:
  - “Open this file”
  - “Run this executable”
  - “Do this 1 thing”

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Exploit creation: What are some properties of an exploit that works really well? (this has a lot of overlap with well-written software)

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Binary Diffing: Create an Exploit

- Weaponize the proof-of-concept
  - Glossing over lots of details here
  - “Left as an exercise for the reader”
- Make it work on multiple systems under as many configurations as possible
- Make it incredibly easy to use

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Binary Diffing: Create an Exploit (Bonus Points)

- Learn Ruby, if you don't already know it
- Write a Metasploit module for your exploit
  - Metasploit is an exploit framework used by security professionals in penetration tests to exploit vulnerabilities and gain footholds on systems and networks
- Come to Cigital and use the exploit in pentests and red team assessments ;)

References

- Recommended papers/tools:
  - http://www.scribd.com/doc/79441056/EUSecWest-2010-DarunGrim-A-Tool-for-Binary-Diffing-and-Automatic-Vulnerabilities-Pattern-Matching
  - http://www.blackhat.com/presentations/bh-usa-09/OH/BHUSA09-Oh-DiffingBinaries-PAPER.pdf
  - http://www.darungrim.org
  - http://www.zynamics.com/bindiff.html

Questions?

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Thank You

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