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Demystifying Debugging and Disassembling Applications

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Part One: Introduction

Disassembly, Disassemblers, and Debuggers

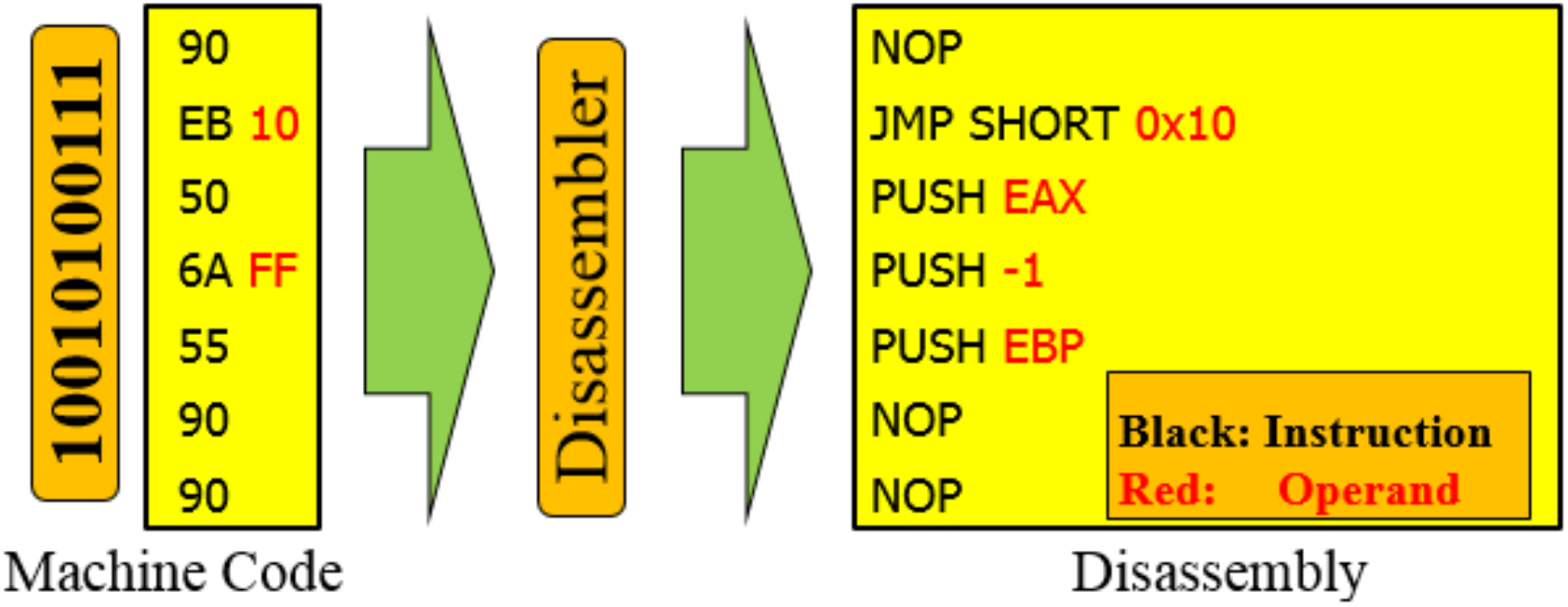
Purpose

- Disassembly and Debugging is used by Application Developers, Security Researchers, Attackers, Malware experts, etc…
  - Disassembly allows you to interpret machine code and map it to its mnemonic representation to perform static analysis
  - Debugging allows you to monitor application behavior in a controlled manner, offering the ability to pause, patch, and examine
  - Decompilation goes even further, converting disassembly back to source code
- Expertise in this area can offer new opportunities
  - Security experts who are adept in reverse engineering are highly sought after
  - Exploit sales can quickly yield into the six figures

Profiting

- Exploit Sales
  - Remote browser or document-based exploits can go for >$10K USD
  - Remote Windows Kernel bugs can go for >$100K USD
  - Zerodium paid $1M USD to a group who disclosed a iOS remote jailbreak exploit - https://www.zerodium.com/ios9.html
- Bug Bounty Examples:
  - United Airlines – Will pay up to 1 million award miles for disclosures
    - https://www.united.com/web/en-US/content/Contact/bugbounty.aspx
  - Google – Will pay various amounts depending on the severity of the bug
    - https://www.google.com/about/appsecurity/reward-program/
  - Microsoft – Will pay up to $100K USD for exploitable bugs and exploit mitigation bypass techniques
    - https://technet.microsoft.com/en-us/library/dn425036.aspx
  - CanSecWest Pwn2Own – Annual conference and challenge in Vancouver, CA offering high-priced bounties
    - https://www.cansecwest.com/

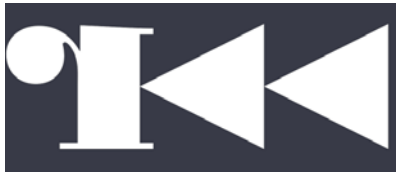
Let's get right to it! What is disassembly?



Tools for Disassembly

- IDA (Interactive Disassembler)
  - Available from Hex-Rays at http://www.hex-rays.com
  - Commercial product with different pricing options
  - Seen as the de facto tool for disassembly

- radare2
  - Available at http://www.radare.org/
  - Free open source reverse engineering framework
  - Offers disassembly, debugging, and many other features



- Many other tools available such as hopper and vivisect

What is Debugging

- Debugging allows us to:
  - Validate and confirm findings made during reverse engineering and static analysis
  - Modify program flow and behavior
  - Set breakpoints at various locations within a program for analysis
  - Determine the exploitability of a potential vulnerability
  - Weaponize and validate the working order of an exploit
  - Learn about application and OS changes made in relation to exploit mitigations

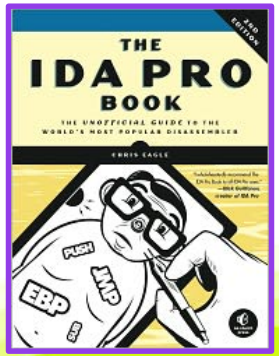
http://dev102.com/Dev102/wp-content/uploads/2008/12/bugs.png

Common Tools for Debugging

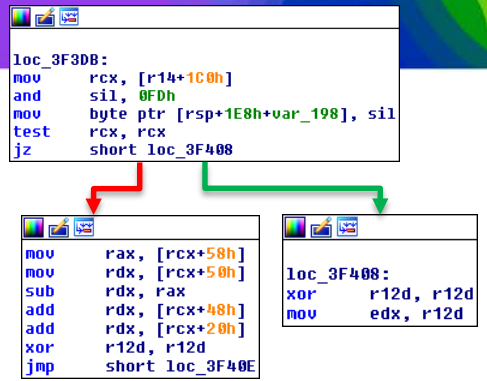
- **WinDbg** – An x86/x64 ring0 and ring3 debugger offered by Microsoft at https://developer.microsoft.com/en-us/windows/hardware/windows-driver-kit
- **Immunity Debugger** – An x86 debugger for Windows maintained by Immunity Security at https://www.immunityinc.com/products/debugger/
- **OllyDbg** – An x86 debugger for Windows maintained at http://www.ollydbg.de
- **GDB** – An open source debugger for UNIX systems available at https://www.sourceware.org/gdb/

IDA

- Interactive Disassembler (IDA)
  - Ilfak Guilfanov – Founder/CEO, Chief Architect, Lead Developer
  - Currently maintained by Hex-Rays in Belgium
  - http://www.hex-rays.com
  - Hex-Rays Decompiler also available to convert compiled C & C++ code back to source
- *Recommended: The IDA Pro Book*
  - *The Unofficial Guide to the World's Most Popular Disassembler* by Chris Eagle



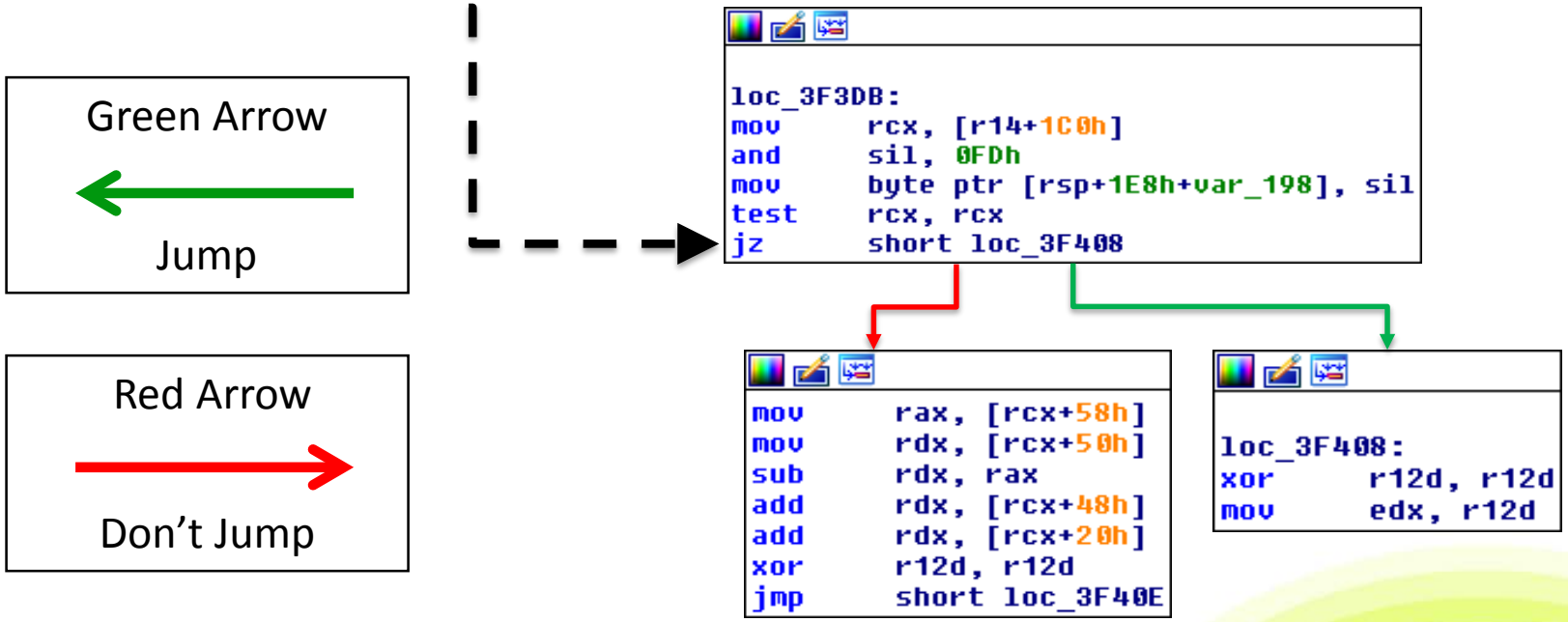
IDA Basics



- Recursive Descent Disassembler
  - Much more complex and effective approach
  - Can tell instructions from data
  - Handles branches such as jumps and calls
  - Defers branch target instructions based on a condition
- Supports multiple debuggers and techniques, including WinDbg, GDB, Bochs emulator, etc.
  - Disassembles many processor architectures including ARM, x86, AMD, Motorola, etc.
  - Provides many different graphical and structural views of disassembled code
  - Reads symbol libraries

Conditions

- Jump on Zero (JZ) and similar instructions



Introduction to IDA Demonstration

- Understanding the basic features of IDA

Scripting with IDA

- IDA Scripting Language (IDC)
  - Proprietary C-like language to interact with the IDA SDK
- IDAPython Plugin allowing Python scripting
  - IDAPython is led by Gergely Erdelyi and available at http://code.google.com/p/idapython/
  - Powerful interface to the IDA SDK and easy to use!
- IDA Plugins
  - IDA plugins are compiled C++ programs that perform actions using the IDA APIs and allow you to greatly expand IDA's capabilities

IDAPython Demonstration

- Using IDAPython to locate banned functions in a program

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Part Two: Patch Reversing

Discovering 1-Day Exploits

Patch Diffing and Reverse Engineering

- What are 1-day exploits?
  - Many researchers and attackers download security patches as soon as they become available
  - Quick bug discovery can lead to exploit development and a large return on investment
- Microsoft started “Patch Tuesday” in the early 2000’s
  - It serves as a way for Windows administrators to prepare for patching
  - …but, Microsoft seems to be heading towards mandatory updates
  - Cumulative patches began in October, 2016
  - Windows as a Service (WaaS) for Windows 10

In the past…

- To obtain security patches you could simply visit Microsoft TechNet
  - Choose the desired patch, download, and grab the prior update

Download the new patch here

Download the old patch here

Microsoft Security Bulletin MS16-106 - Critical

Security Update for Microsoft Graphics Component (3185848)

Published: September 13, 2016

Version: 1.0

Executive Summary

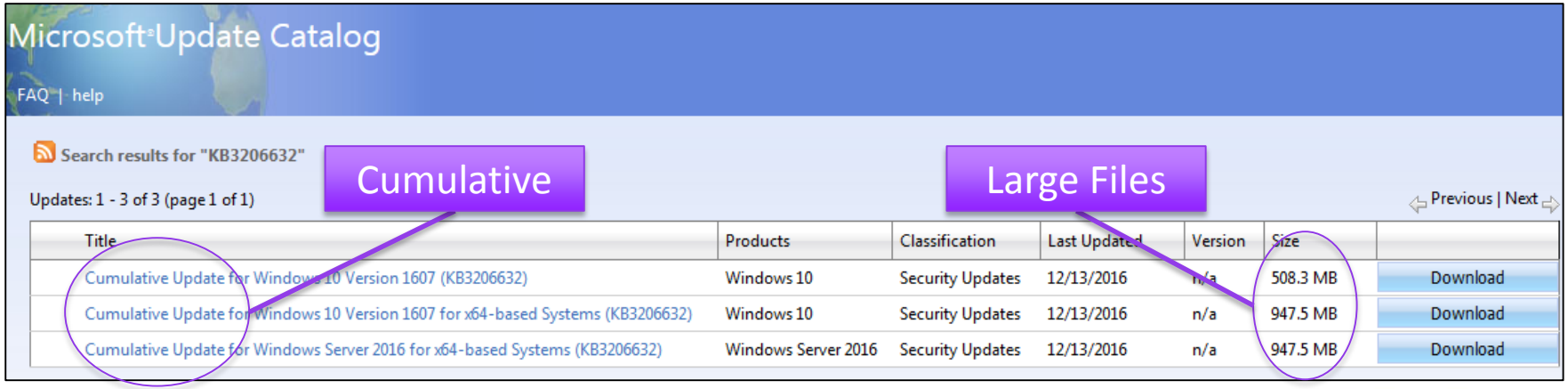
This security update resolves vulnerabilities in Microsoft Windows. The most severe of the vulnerabilities could allow remote code execution if a user either visits a specially crafted website or opens a specially crafted document. Users whose accounts are configured to have fewer user rights on the system could be less impacted than users who operate with administrative user rights.

Microsoft Windows

Operating System	Win32k Elevation of Privilege Vulnerability – CVE-2016-3348	Win32k Elevation of Privilege Vulnerability – CVE-2016-3349	GDI Information Disclosure Vulnerability – CVE-2016-3354	GDI Elevation of Privilege Vulnerability – CVE-2016-3355	GDI Remote Code Execution Vulnerability – CVE-2016-3356	Updates Replaced*
Windows 10						
Windows 10 for 32-bit Systems [2] (3185611)	**Important** Elevation of Privilege	**Important** Elevation of Privilege	**Important** Information Disclosure	**Important** Elevation of Privilege	Not applicable	3176492

Cumulative Updates

- Now patches are rolled up for the entire year and the files are very large



PatchExtract & PatchClean

- Making sense of the way Microsoft is forcing cumulative updates can be a challenge
- Greg Linares (@Laughing_Mantis) wrote tools to help make sense of the cumulative patches
  - PatchExtract extracts all updates from a cumulative update organizes them
  - PatchClean moves any file older than a month into a subdirectory to allow for focus on recently changed files
  - Mapping updated files to their Knowledge Base (KB) number is still a manual process

PatchExtract Demonstration

- Extracting the patches from the February, 2017 Patch Tuesday Update

Reversing Patches to Find Vulnerabilities

- Reversing patches can help a research in various ways
  - Quick discovery and weaponization of the patched vulnerability to a driver or DLL can be extremely lucrative as many organizations fail to patch in a timely manner
  - An understanding of how fixes are made to vulnerabilities can help with 0-day vulnerability discovery
- Using tools available to identify changes between two versions of the same file can greatly decrease analysis time
- Many tools are a available to help

Patch Diffing Tools

- The following is a list of well-known binary diffing tools:
  - **Zynamics/Google's BinDiff:** Free as of March 18, 2016!
  - **Core Security's turbodiff:** Free
  - **DarunGrim 4 by Jeongwook Oh:** Free
  - **patchdiff2 by Nicolas Pouvesle:** Free
  - **Diaphora** by Joxean Koret
  - There are more
- Each use different techniques and heuristics to identify changes

Patch Reversing Demonstration

- Reverse engineering a Microsoft security update to locate a vulnerability

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Part Three: Ring 0 Debugging

Debugging Drivers and the Windows Kernel

The Windows Kernel

- The modern Windows Kernel is very complex, requires intermediate to advanced debugging experience, and preferably low level programming experience

- The majority of the native services and underlying functionality is undocumented
  - You know you're onto something when you Google a symbol and get 0 hits!
  - Much of the Kernel is documented on the underground
- Most operating systems have a two-ring processor access mode architecture: Ring 0 (Kernel) and Ring 3 (User)

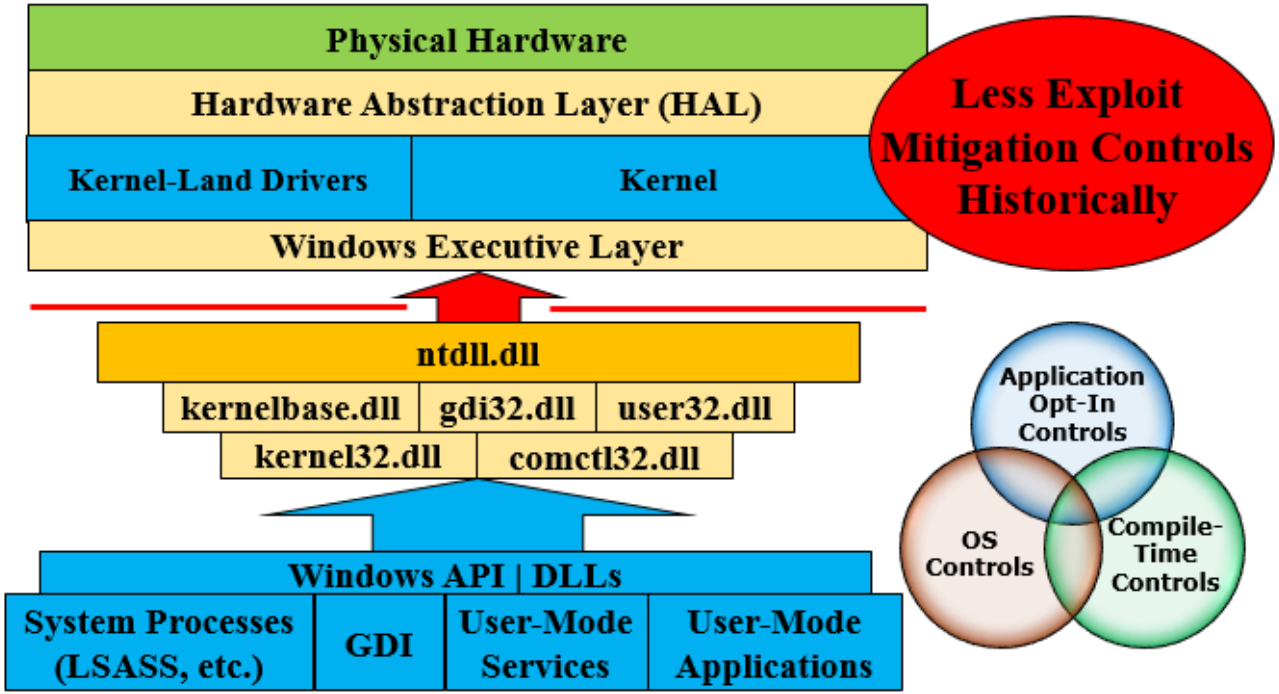
Windows Internals in One Slide

- To gain proficiency of the Windows Kernel and OS internals, you would need to spend countless months studying and reversing
- A quick list of some key items you'd need to ramp up quickly on:
  - Kernel Executive, SRM, Subsystems, System Calls, Kernel Objects
  - Kernel Structures such as EPROCESS, KPROCESS, ETHREAD, KTHREAD, TLS, KPRCB, KPCR
  - The Hardware Abstraction Layer (HAL)
  - Mutexes and SpinLocks
  - Driver behavior (IOCTL, IRP, Bus)

Methods for Windows Kernel Debugging

- VirtualKD by SysProgs – A powerful tool to improve and simplify kernel debugging on Windows
  - Available at http://virtualkd.sysprogs.org/ SYSPROGS
- Serial ports through virtualization applications such as VMware
- Cable-based kernel debugging
  - Ethernet, Null modem, IEEE 1394 (FireWire), USB
- Local Debugging

Attacking the Kernel



Exploit Mitigations

- Historically, user mode has seen more advances in exploit mitigations; however, the Kernel has become much more hardened
- Examples of modern mitigations:
  - Control Flow Guard (CFG)
    - Aimed at stopping Return Oriented Programming (ROP)
  - Browser Specific Controls: MemGC and Isolated Heaps
    - Aimed at stopping Use After Free (UAF) exploitation
  - Kernel Specific Controls: Guard Pages, Kernel Pool Cookies, Null Ptr Deref Prot
  - Proposed Mitigations: Shadow Stacks and Control Flow Integrity (CFI)
  - Oldies but Goodies: ASLR, DEP, Canaries, Safe Unlink, LFH, EMET**

Kernel Debugging Demonstration

- Connecting to the Windows Kernel using VMware and VirtualKD

How to Apply Today's Subject Matter

- When returning to work:
  - Audit the patch management program in your organization and ensure critical patches are quickly and safely applied
    - This applies to non-Microsoft products as well, which are often more difficult to manage in relation to patch awareness
  - Identify members of your security staff who have skills in reverse engineering and debugging
    - Understand how they are currently using these skills and look for opportunities for improvement
  - Inform others as to the risks of delaying security updates
    - Demonstrations can greatly help to gain support

Questions?

- Thank You!

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