(un)Smashing the Stack
(Overflows, countermeasures, and the real world.)

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Hey, who is this guy?

- Attacker by nature, defender by trade
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- IRDF, WebAppSec, “Architect” ← (LOLOLOL)
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- IRDF, WebAppSec, “Architect” ← (LOLOLOL)
- Obsessive-compulsive quixotic insomniac with messianic tendencies
#include std_disclaimer.h

My humble attempt to understand a complex topic.
Whiskey Tango Foxtrot?

- The Exploitation Wayback Machine™
  - What did Lincoln say about history?
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Exploit Mitigation
- Compile bits, lib bits, kernel bits
- Memory integrity, canaries
- Anti-heterogeneity (ASLR, PIC/PIE)
Whiskey Tango Foxtrot?

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- Bonus defensive fu
  - MAC / MIC
  - Static analysis
  - Rubber meets the road
InfoSec is a fork bomb

- Patch Then Scan Then Patch Then Scan Then Patch Then Scan Then Patch Then Scan Then ...

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- Retrofit of the 80’s antivirus model
  - Patches (and exploits) on a subscription basis
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- Getting a bit old, innit?
Breaking the membrane

- Corruption of memory space == control of execution flow
- Hilarity ensues.
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- As far back as the 1960’s...
  - Overrun screw, wild pointer, stack scribbling, fandango on core
@ pre-epoch
@ the epoch
In the age of the dinosaurs

- Spaff’s Morris doc + RFC 1135, circa 1988
  - Stack-based BO in fingerd gets() call
  - Spaff: Avoid unsafe calls in C, mmm-kay?
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- [http://www.securityfocus.com/bid/2](http://www.securityfocus.com/bid/2)

- Happy 20th birthday, cluephone.
Things get interesting

- Lopatic, circa 1995
  - Stack-based BO in NCSA httpd
  - “Looks like Morris”... Hrmm.
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- Mudge, circa 1995
  - “How to write buffer overflows”
  - Shellcode w/o ASM, NOP sleds
Curiouser and curiouser

- Aleph One, circa 1997
  - Snapshot of attack landscape in the 90’s
  - Memory segments, “eggs”, NOPs
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  - Ret2libc: call preloaded functions in payload
  - Works without stack execution
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- **Conover / woowoo, circa 1999**
  - “woowoo on heap overflows”
  - Writes to the heap, function ptr overwrites
NIST NVD remote BO’s
One more time, for the CISSPs
Nonexecutable stacks

- Data is data, code is code, right?
- Ne’er the twain shall meet
Stack prophylactics

- Solaris / uSparc
  - noexec_user_stack = 1
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- nX, XD, on IA64, AMD64, others
  - PAE bit 63 0/1
  - Opt-in: OS, libs, etc must flip this bit
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- Software emulation
  - Less fine-grained (Segment-based)
  - Solar’s StackPatch, PaX, MS DEP, RH ExecShield
Functionality breeds exposure

- Some breakage may occur in shipment
  - JIT compilers, Virtualization
  - Wha? I can’t run my CP/M z80 emulator?
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- User-configurable opt-outs
  - ProcessExecuteFlags
  - Mprotect(), VirtualProtect()
Counter-countermeasures

- **Ret2libc**
  - Call preloaded functions
  - Call mprotect(), set new allocation rwx
  - Needs “known” useful address
Counter-countermeasures

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- **Heap-based overflows**
  - More interesting nowadays
  - Little protection on the heap at this point
Counter-countermeasures (deux)

- Piromposa / Embody
  - “Hannibal attack”
  - Function ptr overwrite, shellcode via argv
Counter-countermeasures (deux)

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- Skape / Skywing
  - Forcible opt-out in MS DEP via ret2libc
  - MEM_EXECUTE_OPTION(ENABLE|DISABLE)
  - “/noexecute=AlwaysOn” boot.ini flag
Optional security, isn’t.
  - Compiler flags rarely on by default
  - Most optimization flags disable checks
  - Trampolines, workarounds, other ugliness
Canary in a coalmine

“Tripwire for the stack”

- Compiler extensions to detect corruption
- Initially, canary value of RTA (StackGuard)
- Halt execution if value changes (function_epilogue)
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- ProPolice / SSP
  - GCC > 4.1 integration, backports
  - MS adopted as /GS extensions
  - "Guard value", stored off-stack
  - Beyond canaries: Well-ordered stack
Propolis
Safe Stack

Arguments
RTA
PFP
Guard Page
Arrays
Local Variables

Args grow up. Stack grows down.
(un)Smashing the Heap!

- Heap canary implementations!
  - Guard values around malloc()

- OpenBSD “G” option to malloc.conf

- Contrapolice
  - [http://synflood.at/contrapolice.html](http://synflood.at/contrapolice.html)

- wkr’s dlmalloc extensions
Killing the canary

- Gerardo of CoreSec:
  - GOT and PLT writes, SFP overwrites
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- HERT, Phrack 56
  - RTA-only problems in StackGuard
  - Overwrites to RTA without harming canary
Killing the canary (deux)

- Canary as target
  - Arbitrary memory reads, format string bugs
  - /proc/mem, other info leakage
Anti-heterogeneity

- PaX
  - The originator of this concept.
  - Userland, kstack, mmap()
  - Tunable knobs (paxctl / sysctl)
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- **OBSD 3.3+**
  - Randomized malloc(), mmap(), gaps / fencing
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- ExecShield
  - Stack, base randomization, also noexec
Anti-heterogeneity (deux)

- Vista
  - Random .exe and .dll loader
  - /dynamicbase flag, opt-in model
  - Weaker on the heap (see Whitehouse/BHDC07)
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- Leopard
  - Randomized libs, not heap or stack
  - Mach arch limitations – some fixed addresses
Anti-heterogeneity (trois)

- PIC or PIE
  - Execute sanely, regardless of location
  - Find the GOT and get random
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- Key to full ASLR
  - Without, only defended against ret2libc
  - $1$ in $2^{(STACK\_RAND + MMAP\_RAND)}$
Elegant solution, meet brute force.

- **Hovav Shacham**
  - Derandomization attack
  - Brute-force system() on forking service
  - What about client-side? Browser?
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- Bonus unrelated cool Hovav stuff
  - ret2libc without function calls
  - Sequence chaining, “gadgets”
Brute force (deux)

- Ben Hawkes
  - Code-access brute-forcing
  - Unsuccessful reads to get ret2libc
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  - Code-access brute-forcing
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- Whitehouse / BHDC07
  - Varying degrees of randomization in Vista
  - Especially on heap
Exploit Mitigation: Cliff’s Notes

- Noexec / NX
  - If runtime configurable it’s pointless
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- Canaries
  - Bad crypto != panacea
  - All memory space requires protection
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- ASLR
  - Bad crypto != panacea
  - Memory leaks, inconsistencies
Other ways to skin a cat

- Fix the @#$% code?
  - RATS, Flawfinder, FORTIFY_SOURCE
  - Lots of commercial stuff, obviously
  - DHS / Coverity joint project
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- Rice’s Theorem, Rumsfeld’s Corollary
  - Automated analysis goes only so far
  - Unknown unknowns
Cat skinning redux

- Access control models
  - Post-exploit containment
  - File, device, inode
Cat skinning redux

- Access control models
  - Post-exploit containment
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- Another way to contain exposure
  - Varying degrees of complexity
  - Linuces, Vista, BSDs, now Leopard
Rubber, meet road.

- **PaX**
  - “The guaranteed end of arbitrary code execution”
  - SEGMEEXEC, PAGEEEXEC, sigtramp emulation
  - ASLR in userland, kstack
  - Configurable bits for misbehaving binaries

- **Integration**
  - [http://kernelscet.eo.org](http://kernelscet.eo.org)
  - Hardened Gentoo, Ubuntu-Hardened
Rubber, meet road (deux)

- OpenBSD
  - First to integrate ProPolice / SSP
  - Heap canaries, W^X, ASLR
  - Mprotect () works, no rand or noexec for kstack

- FreeBSD
  - Very basic NX, other projects to add SSP

- NetBSD
  - Adding SSP, PaX-inspired bits to 4.0
Rubber, meet road (trois)

- **Vista**
  - ASLR, PIC/PIE, MIC, DEP / NX
  - Consistency is an issue
  - What is Crispin doing?

- **2003 / XP**
  - DEP/NX, canaries
  - Wehnus!  [http://www.wehnus.com](http://www.wehnus.com)
Rubber, meet road (quatre)

- OSX Leopard
  - First toe in the water
  - Simple NX, heap remains executable
  - Seatbelt.kext / sandboxing based on policies
  - ASLR limitations due to Mach arch
Do you feel safer yet?

- Time to fire Von Neumann?
  - The computing model needs to change.
  - Compartmentalized Operating Systems?
  - Academia, where are you?
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  - Legacy support, compatibility
  - Opt-in models for consumer OS’s
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- Defenders need to understand this
  - Jon Erickson is teh awesome+++ 
  - What’s in your stack?
Thanks for listening.

- http://pax.grsecurity.net
- http://www.wehnus.com

- Thanks to DT, Ping, Dom, BH goons
- Much love to everyone working on this!