State of the Hardened Union

vBSDcon

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whoami

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- Cofounder of HardenedBSD
- President of the HardenedBSD Foundation
- Open source offensive and defensive work
- Human rights and anti-censorship work
- Perpetual newb

Agenda

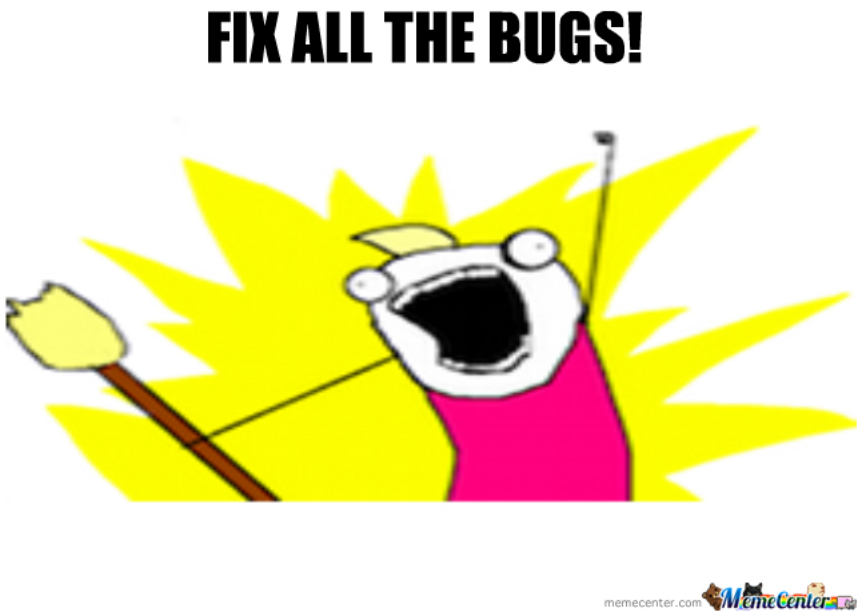
- Background
- Introduction to various exploit mitigations, focus on userland
  - W^X, PaX NOEXEC, DEP
  - ASLR
  - PaX SEGVGUARD
  - Control Flow Integrity
  - Code Pointer Integrity (chiefly: SafeStack)
  - CHERIBSD (primarily hardware-based)
- Security postures
- Call for participation
- Questions / comments

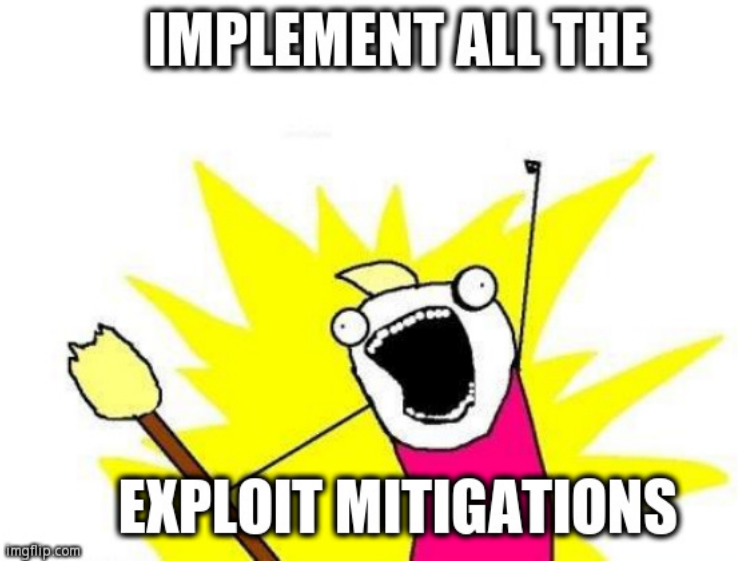
Background

- Back in my day...

Background

- Humans write code
- Humans are imperfect
- Imperfect code causes imperfect human
  - ...Or is it the other way around?





Intro to PaX NOEXEC

- PaX model:
  - At mmap time (PaX PAGEEXEC):
    - When page is writable, it can never be executable
    - When page is executable, it can never be writable
    - When page is both, silently drop executable
  - At mprotect time (PaX MPROTECT):
    - When page is writable, it can never be executable
    - When page is executable, it can never be writable
  - (PAGEEXEC + MPROTECT) = NOEXEC
  - Commonly breaks JITs. Implementors of the PaX model usually (always?) provide toggles for those very few applications violating PaX NOEXEC.
  - NetBSD and HardenedBSD
    - Interesting HardenedBSD commit: 0b951237eee70314b6d40f8fc7ea7fd77d312466

Intro to W^X (W xor X)

- OpenBSD model (aka, W^X):
  - Cannot create RWX pages
  - Can toggle between writable and executable
  - User-visible toggle: wxneeded for filesystem and binary
- FreeBSD model:
  - Application opt-in via new PROT_MAX macro added 30 Jun 2019
    - Do not allow page to have permissions not set in maxprot
    - Requires source-level modifications
    - procctl
- PaX model most strict
  - Breaks JITs, needs toggles
  - Provides highest level of security
- Windows term: Data Execution Prevention (DEP)
- “W^X” now generic term

Defeating W^X

- Assuming lack of AS[L]R
- 1997 saw ret2libc
  - NX stack defeat
  - Variants on a theme: ROP (2008), SROP, JOP, BROP
    - Code reuse attacks
- Shows need for AS[L]R and SEGVGUARD
- If attacker knows address space, game over

Address Space [Layout] Randomization

- Probabalistic defense against ret2libc-style attacks
- ASLR uses deltas generally computed at image activation (execve) time, ASR does not use deltas
  - Outliers:
    - Windows: Per-boot deltas (part of why suspend/resume on Windows dangerous)
    - FreeBSD: Partial ASR
    - OpenBSD: ASR
    - macOS: Weird mix of ASLR and ASR
- Requires address space contain zero interesting non-fixed mappings
- Position-Independent Executables (PIEs)

Address Space [Layout] Randomization

- PaX ASLR strongest form. On HardenedBSD, deltas computed at image activation:
  - PIE execution base
  - mmap(~(MAP_FIXED))
  - Stack (randomized stack top + randomized stack gap)
  - Shared page (hope to someday call this a VDSO on FreeBSD/HardenedBSD)
  - 64-bit systems: mmap(MAP_32BIT & ~(MAP_FIXED))
    - MAP_32BIT support disabled by default on HardenedBSD

Address Space [Layout] Randomization

- Propped up on pedastal
- Improper threat modeling
  - Somehow started to include browsers
- Helps frustrate remote attacks
- Weaknesses:
  - Information leak vulnerabilities
  - Certain format string vulnerabilities
  - Multi-tenancy / shared trust
- Combination of ASLR + DEP forever changed exploitation
  - Now must chain multiple vulnerabilities
  - Can fully render non-exploitable some real-world vulnerabilities

PaX SEGVGUARD

- Deterministic defense against unreliable exploitation
- Code reuse attack payload generation generally causes lots of crashes
- Track number of crashes in sliding window
- Attempt to exceed threshold result in temporary suspention of execution
- Similar to password bruteforce prevention
- Available in NetBSD and HardenedBSD
  - NetBSD: disabled by default due to memory constraint concerns
  - HardenedBSD: disabled by default due to performance concerns

Offensive Trends

- ASLR + DEP + SEGVGUARD drastically increase economic cost of successful attack
- Abusing function pointers
- Out-of-order execution (ROP and its variants)
- Data as code
- 2019 introduced multiple vulnerabilities in telnet
- Attackers paying closer attention to commit logs than defenders

Control Flow Integrity

- Multiple implementations
  - PaX Reuse Attack Protector (RAP)
  - Microsoft Control Flow Guard (CFG)
  - llvm Control Flow Integrity (CFI)
- RAP covered by multiple patents (unknown status), requires GPLv3 compiler toolchain (gcc > 4.2)
- CFG too lax
- llvm CFI incomplete, but most relevant to BSDs
  - Needs tight integration with both libc and the RTLD
  - ifunc in libc fallout
- HardenedBSD adopting llvm CFI
  - Non-Cross-DSO CFI: In use
  - Cross-DSO CFI: In development

Code Pointer Integrity - SafeStack

- Deterministic defense against arbitrary code execution
- Multiple implementations
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CHERIBSD

- Research hardware and FreeBSD derivative
- Hardware-enforced bounded capability model
  - Even pointers have capabilities
- Parts have made it into FreeBSD
  - Naturally FreeBSD-centric
- ARM picking up at least some of their work
- Problem: hardware-based solutions take multiple decades
  - Intel CET
  - SMAP
  - MPX
  - ARMv8.5

Technical security posture

- The good:
  - Collectively, the BSDs have come a long way
  - Paving the road in academia
  - Providing solutions that span decades
  - Each BSD provides different solutions to reach similar/same goals
- The not-so-good:
  - Occasionally stuck in academia
  - Lack of understanding
  - “We don’t need <X> because we have <Y>”
  - “<X> is dead!”

Political security posture

- Late or no advance notice
- Perception of violating embargoes
- Not considered large enough audience
  - Community fragmentation due to BSD fragmentation
- Lack of vendor representation

Community security posture

- Secure collaboration crucial
  - 2016: 25+ year old vulnerability in libc
  - CPU microarchitecture vulnerabilities
- Fragmentation leads to need for collaboration
- We need to build the foundation
  - Start even below the basement
- Lives are at stake
  - Remember Marta?
- HardenedBSD is building that foundation for collaboration

Call for Participation

- Increasing fragmentation of the BSDs
- Shared history, shared code
- Immediate needs:
  - Collaborate on security issues
  - Incentivize fair play
  - Centralized location for outside entities reporting issues
- Long-term needs:
  - Everything else
  - Literally
- bsdsec_collab@hardenedbsd.org
  - Invite-only for now
  - Please email shawn.webb@hardenedbsd.org or talk to me here at vBSDcon
  - 3mdeb, open source firmware vendor, first vendor on the list

Huntington Ingalls Industries

Hard Stuff Done Right ™

Technical Solutions Division

HII is NOT currently hiring:

- Arrogant Security Engineers with over-inflated egos
- Self-centered Java developers with NO interest in teambuilding
- Unethical Business Developers with dollars signs in their eyes
- "C Players" with little/no creativity or curiosity
- Complacent Systems Engineers with 8+ years of laziness under their belts
- Computer Scientists who resist change and/or accept the status quo "yawn"
- Cloud Developers who have no interest in producing highly valuable solutions

The following skills are NEVER required NOR desired:

- Consistent production of low-quality deliverables
- Excellence in blowing off deadlines and presenting excuses
- Proficiency in overlooking the needs of some, while talking down to others
- Experience sabotaging group-thinking sessions with ego-driven participation
- Effectively managing your time so that you have absolutely NOTHING to show for all your hard work
- The uncanny ability to overlook **FUN** at work

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