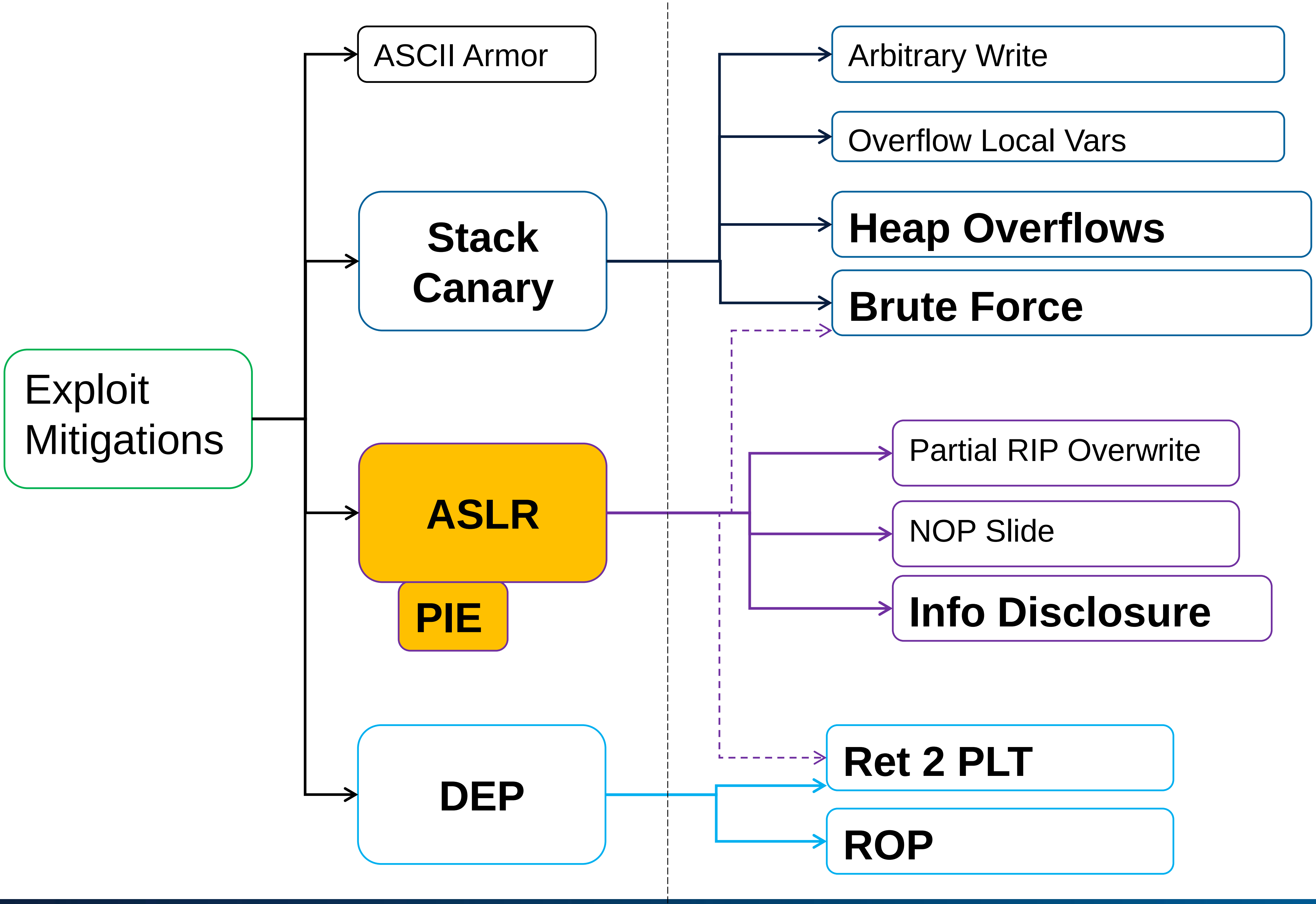
Exploit Mitigation - PIE



Exploit Mitigations

ASCII Armor

Stack Canary

ASLR

PIE

DEP

Arbitrary Write

Overflow Local Vars

Heap Overflows

Brute Force

Partial RIP Overwrite

NOP Slide

Info Disclosure

Ret 2 PLT

ROP

Recap! Exploit Mitigation Exploits

All three exploit mitigations can be defeated by black magic

Easily

Is there a solution?

Exploit Mitigation - PIE

The solution

The solution to all problems… PIE

Exploit Mitigation++

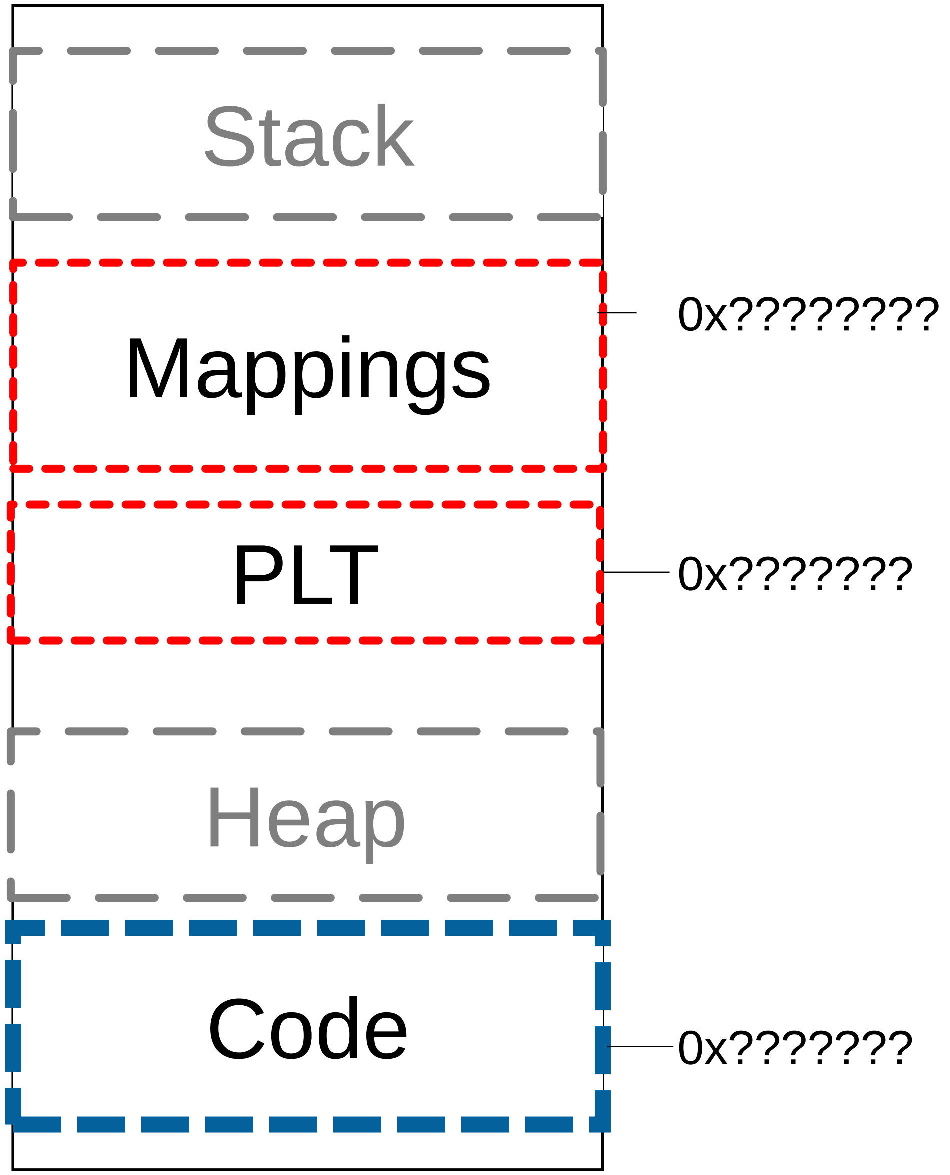
Fix:

- Compile as PIE
- PIE: Position Independent Executable
- Will randomize Code and PLT, too

Note:

- Shared libraries are PIC
    - (Position Independent Code)
- Because they don’t know where they are being loaded
- Always randomized, even without PIE

Exploiting: ASLR for code: PIE



PIE Executable

```
$ cat test.c
#include <stdio.h>

void func() {
        printf("\n");
}
void main(void) {
        printf("%p\n", &func);
}
$ gcc -fpic -pie test.c
$ ./a.out
0x557d9dee57c5
$ ./a.out
0x5581df9d67c5
```

PIE Executable

```
Type           Offset             VirtAddr           PhysAddr
                 FileSiz            MemSiz              Flags  Align
  PHDR           0x0000000000000040 0x0000000000000040 0x0000000000000040
                 0x00000000000001f8 0x00000000000001f8  R E    8
  INTERP         0x0000000000000238 0x0000000000000238 0x0000000000000238
                 0x000000000000001c 0x000000000000001c  R      1
      [Requesting program interpreter: /lib64/ld-linux-x86-64.so.2]
  LOAD           0x0000000000000000 0x0000000000000000 0x0000000000000000
                 0x00000000000009dc 0x00000000000009dc  R E    200000
[…]
 Segment Sections...
   00
   01      .interp
   02      .interp .note.ABI-tag .note.gnu.build-id .gnu.hash .dynsym .dynstr .gn
u.version .gnu.version_r .rela.dyn .rela.plt .init .plt .text .fini .rodata
```

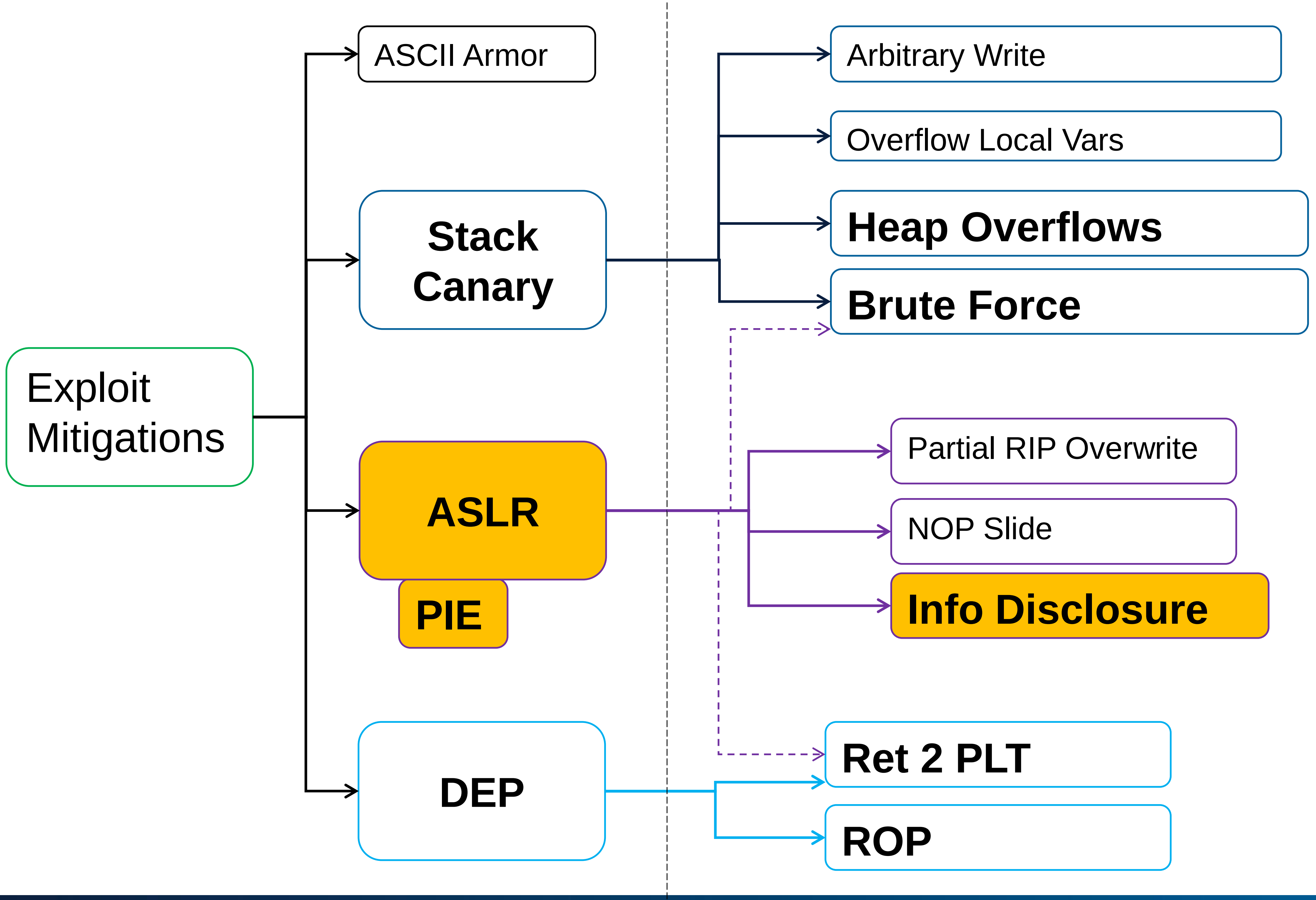
Exploiting: ASLR for code: PIE

PIE randomizes Code segment base address

PIE randomizes GOT/PLT base address too

No more static locations!

Defeat Exploit Mitigation: PIE



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[the cake is a lie]

ASLR vs Information Leak

ASLR assumes attacker can’t get information

What if they can?

Meet: Memory Leak

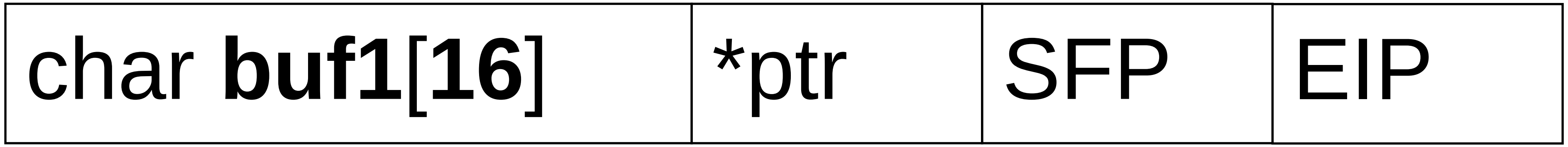
Memory Leak / Information Disclosure

Memory Leak

Memory leak or information disclosure:

- Return more data to the attacker than the intended object size
- The data usually includes meta-data, like:
  - Stack pointers
  - Return addresses
  - Heap-management data
  - Etc.

ASLR vs Memory Leak



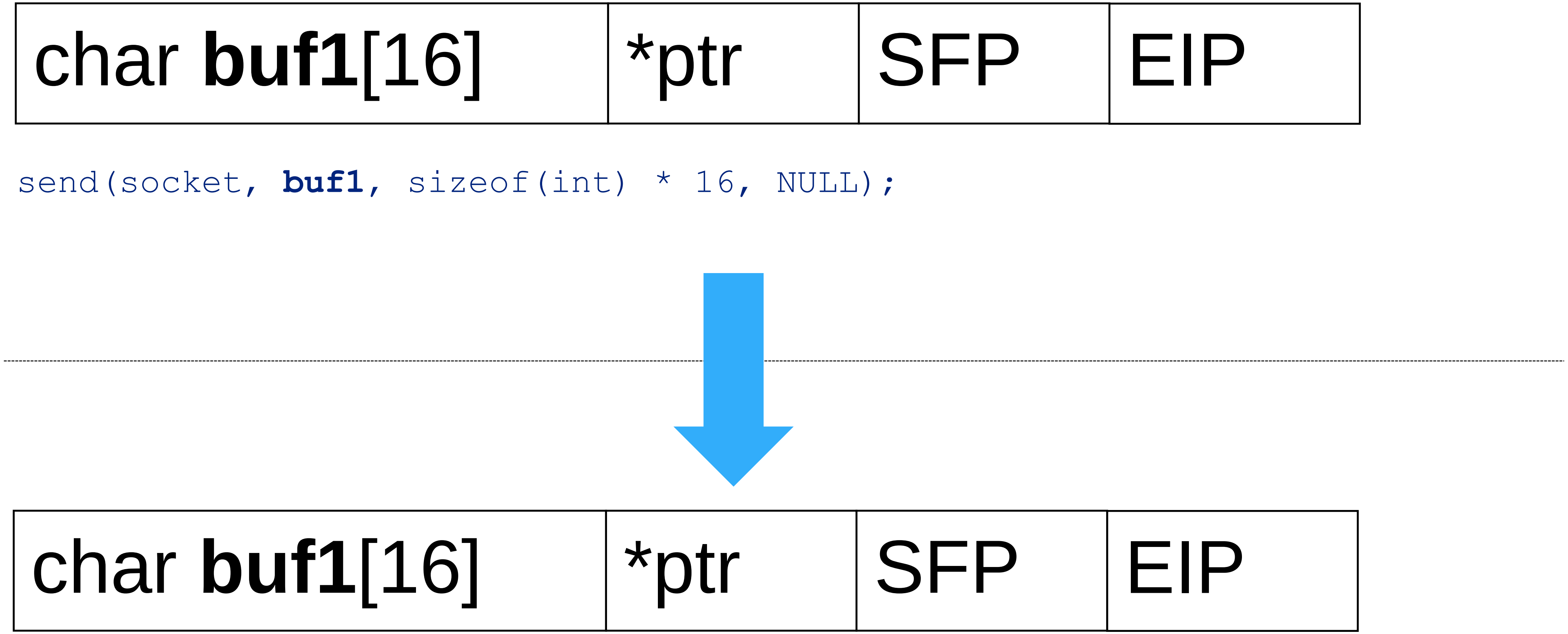
char **buf1[16]** | *ptr | SFP | EIP

Server:

```
send(socket, buf1, sizeof(int) * 16, NULL);
```

- Oups, attacker got 64 bytes back
  - Pointer to stack, code, heap
  - Can deduce base address

ASLR vs Memory Leak

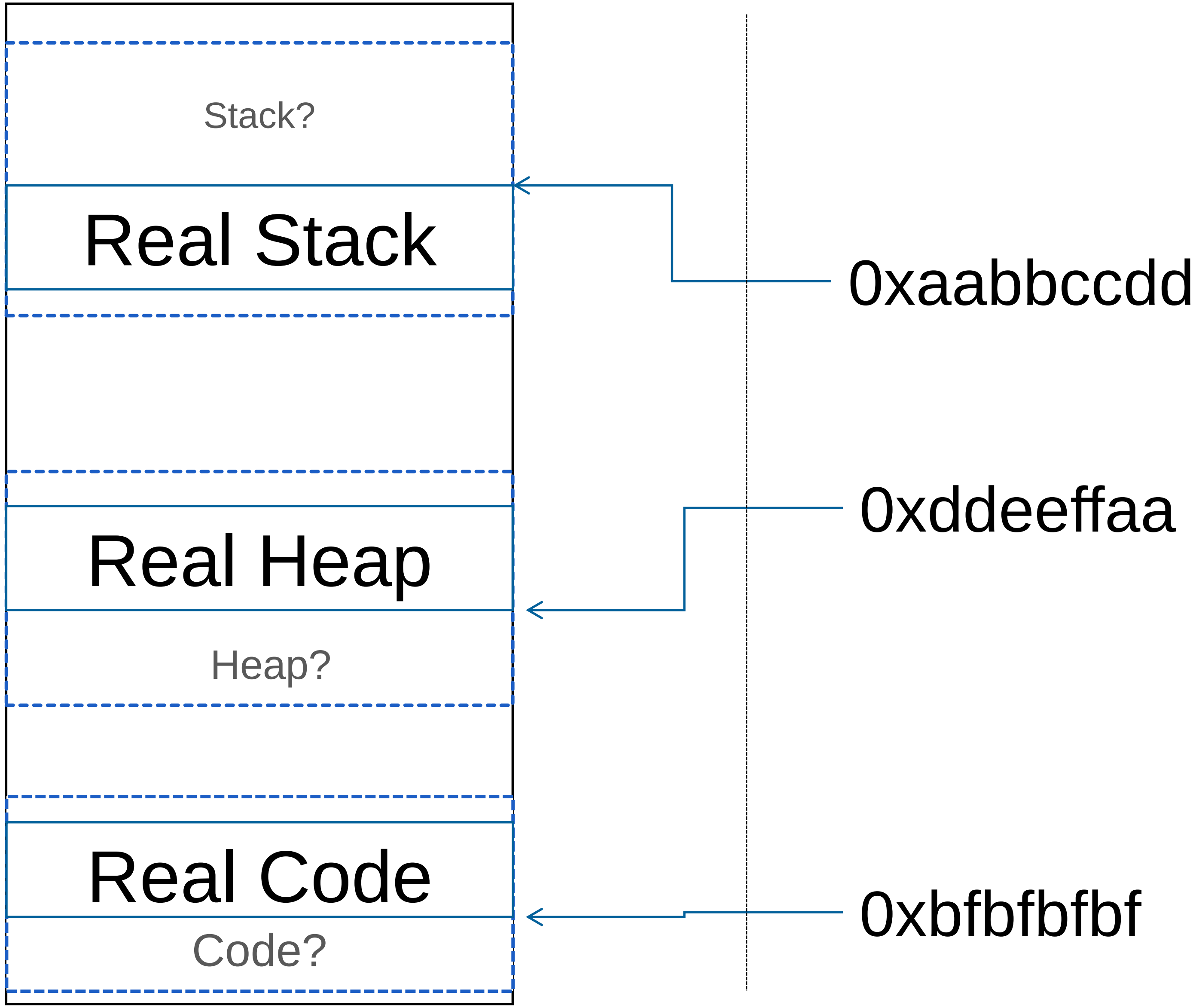


char **buf1**[16]	*ptr	SFP	EIP

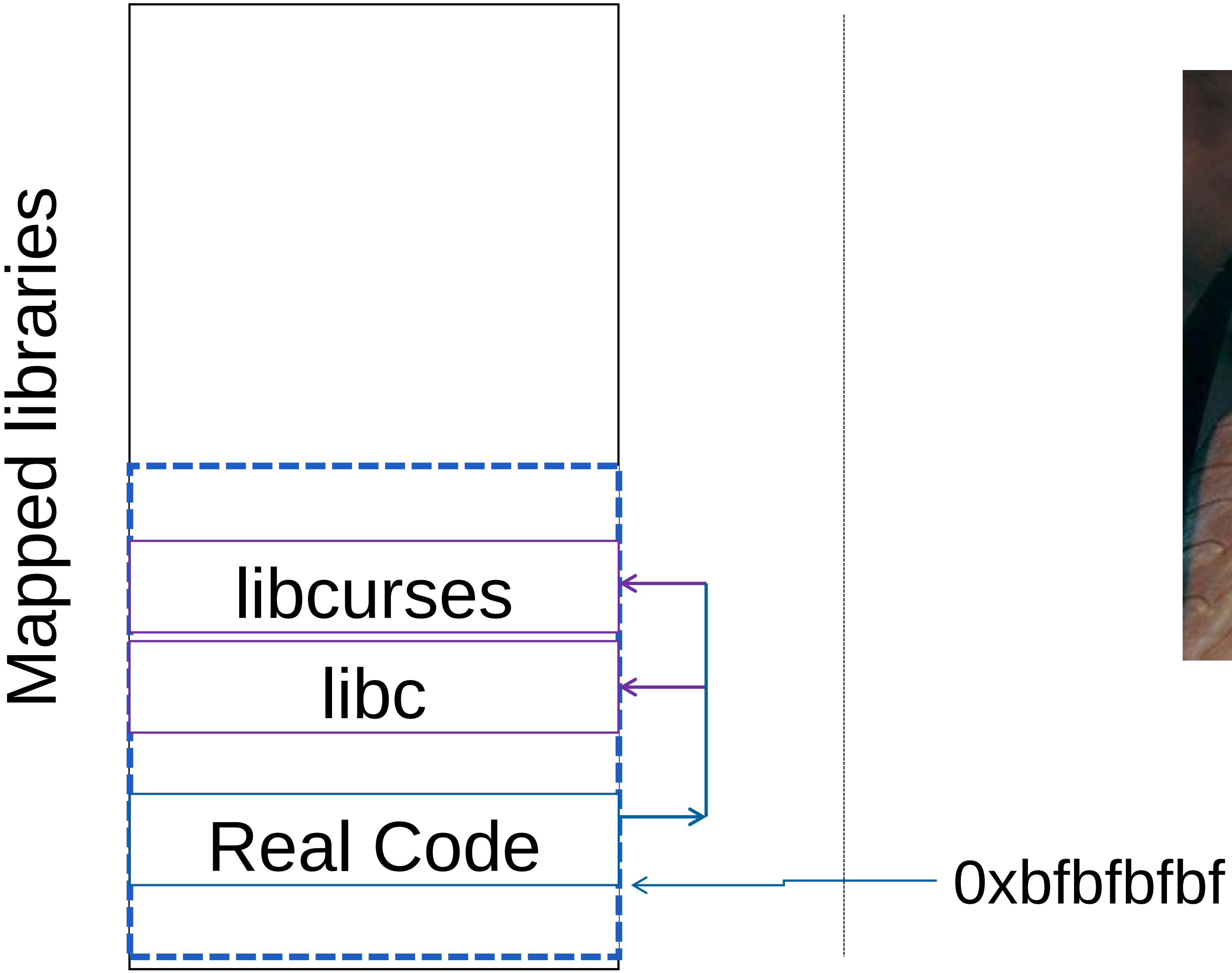
```
send(socket, buf1, sizeof(int) * 16, NULL);
```

char **buf1**[16]	*ptr	SFP	EIP

Exploiting: ASLR for code: PIE



Exploiting: ASLR for code: PIE



Exploiting: ASLR for code: PIE

Attacker:

- Information disclosure / memory leak
- Gains a pointer (Address of memory location)
- From pointer: Deduct base address of segment
- From base address: Can deduct all other addresses

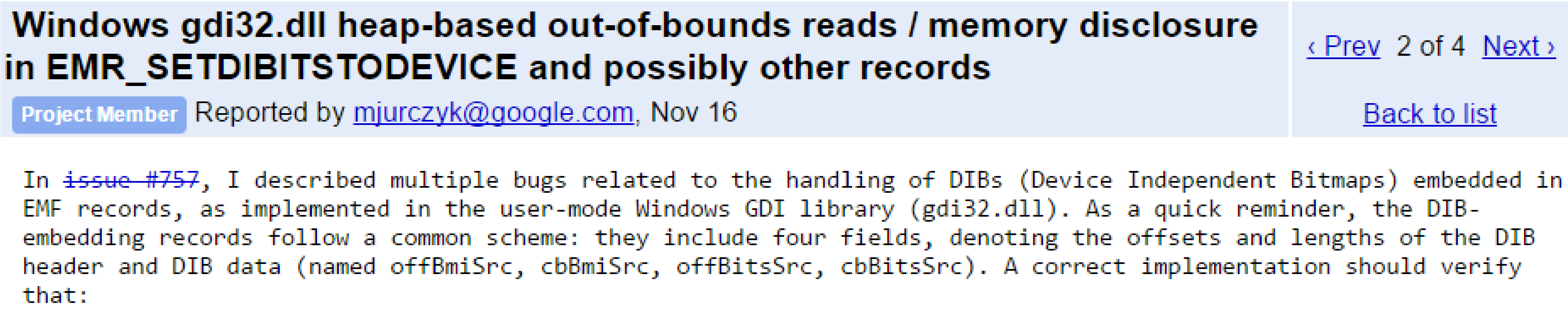
~~A note on code -> libraries:~~

- ~~Distance between code segment and mapped libraries is usually constant~~
- ~~Got SIP? Can use LIBC gadgets…~~

Exploiting: ASLR for code: PIE

Example: Windows memory disclosure (unpatched, 21.2.17, CVE-2017-0038)

As a consequence, the 16x16/24bpp bitmap is now described by just 4 bytes, which is good for only a single pixel. The remaining 255 pixels are drawn based on junk heap data, which may include sensitive information, such as private user data or information about the virtual address space.

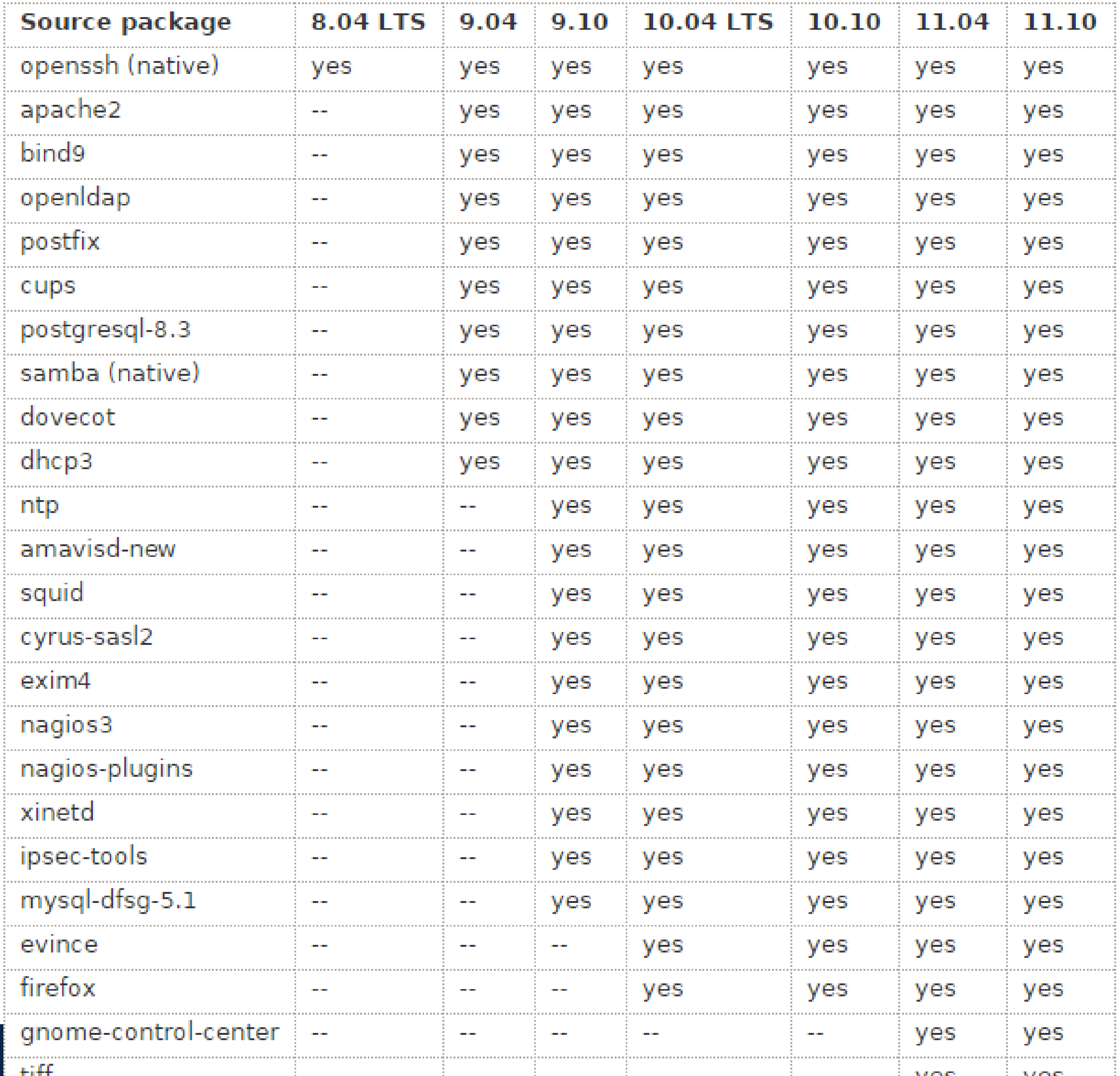


Windows gdi32.dll heap-based out-of-bounds reads / memory disclosure in EMR_SETDIBITSTODEVICE and possibly other records

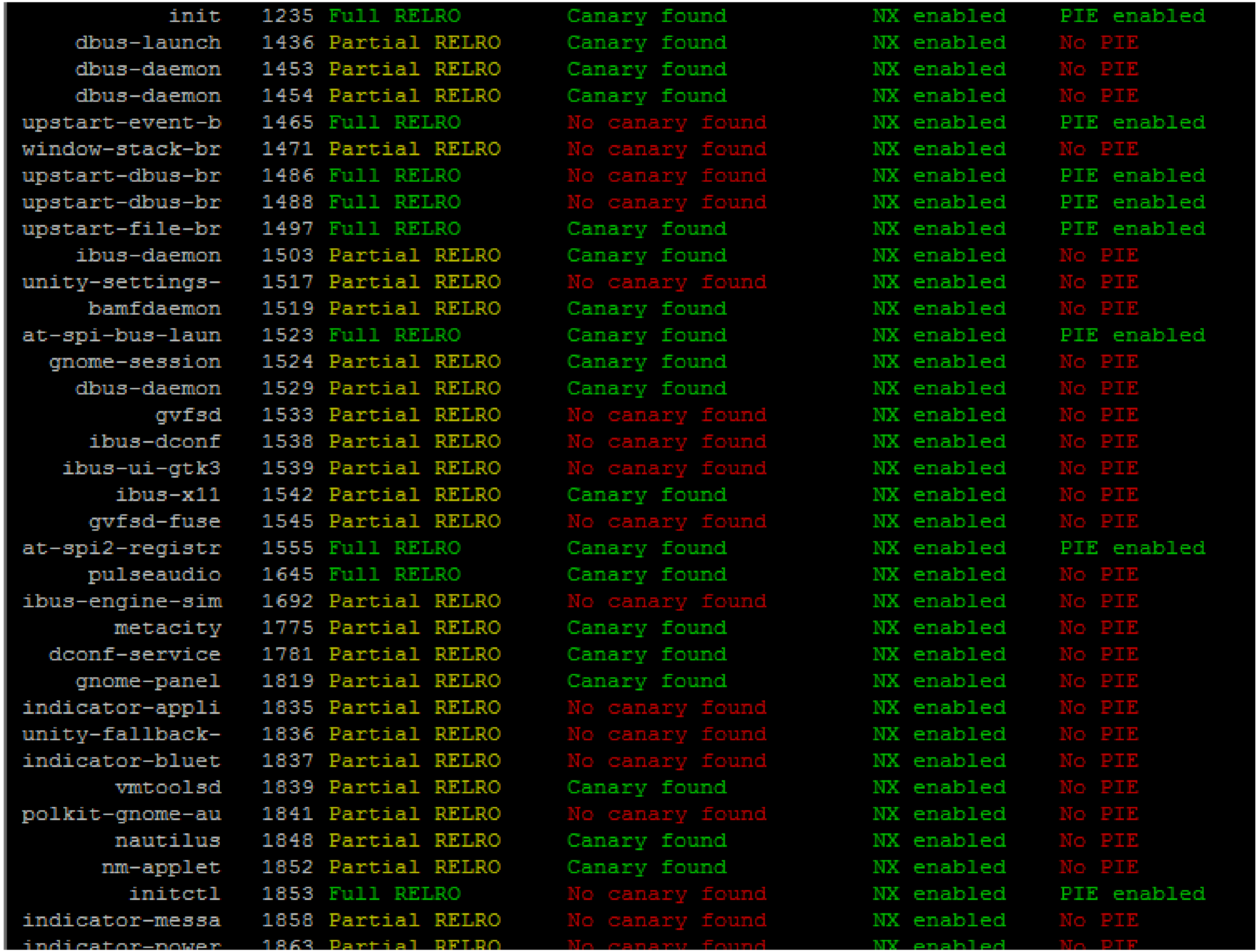
Project Member Reported by mjurczyk@google.com, Nov 16

In ~~issue #757~~, I described multiple bugs related to the handling of DIBs (Device Independent Bitmaps) embedded in EMF records, as implemented in the user-mode Windows GDI library (gdi32.dll). As a quick reminder, the DIB-embedding records follow a common scheme: they include four fields, denoting the offsets and lengths of the DIB header and DIB data (named offBmiSrc, cbBmiSrc, offBitsSrc, cbBitsSrc). A correct implementation should verify that:

Linux Ubuntu Hardening

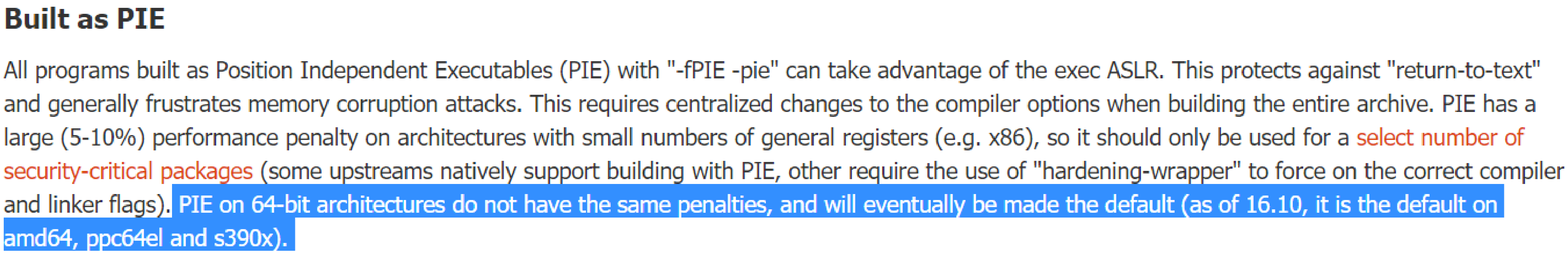


Source package	8.04 LTS	9.04	9.10	10.04 LTS	10.10	11.04	11.10
openssh (native)	yes	yes	yes	yes	yes	yes	yes
apache2	--	yes	yes	yes	yes	yes	yes
bind9	--	yes	yes	yes	yes	yes	yes
openldap	--	yes	yes	yes	yes	yes	yes
postfix	--	yes	yes	yes	yes	yes	yes
cups	--	yes	yes	yes	yes	yes	yes
postgresql-8.3	--	yes	yes	yes	yes	yes	yes
samba (native)	--	yes	yes	yes	yes	yes	yes
dovecot	--	yes	yes	yes	yes	yes	yes
dhcp3	--	yes	yes	yes	yes	yes	yes
ntp	--	--	yes	yes	yes	yes	yes
amavisd-new	--	--	yes	yes	yes	yes	yes
squid	--	--	yes	yes	yes	yes	yes
cyrus-sasl2	--	--	yes	yes	yes	yes	yes
exim4	--	--	yes	yes	yes	yes	yes
nagios3	--	--	yes	yes	yes	yes	yes
nagios-plugins	--	--	yes	yes	yes	yes	yes
xinetd	--	--	yes	yes	yes	yes	yes
ipsec-tools	--	--	yes	yes	yes	yes	yes
mysql-dfsg-5.1	--	--	yes	yes	yes	yes	yes
evince	--	--	--	yes	yes	yes	yes
firefox	--	--	--	yes	yes	yes	yes
gnome-control-center	--	--	--	--	--	yes	yes
tiff						yes	yes



```
           init    1235 Full RELRO         Canary found          NX enabled    PIE enabled
    dbus-launch    1436 Partial RELRO      Canary found          NX enabled    No PIE
    dbus-daemon    1453 Partial RELRO      Canary found          NX enabled    No PIE
    dbus-daemon    1454 Partial RELRO      Canary found          NX enabled    No PIE
upstart-event-b    1465 Full RELRO         No canary found       NX enabled    PIE enabled
window-stack-br    1471 Partial RELRO      No canary found       NX enabled    No PIE
upstart-dbus-br    1486 Full RELRO         No canary found       NX enabled    PIE enabled
upstart-dbus-br    1488 Full RELRO         No canary found       NX enabled    PIE enabled
upstart-file-br    1497 Full RELRO         Canary found          NX enabled    PIE enabled
    ibus-daemon    1503 Partial RELRO      Canary found          NX enabled    No PIE
unity-settings-    1517 Partial RELRO      No canary found       NX enabled    No PIE
     bamfdaemon    1519 Partial RELRO      Canary found          NX enabled    No PIE
at-spi-bus-laun    1523 Full RELRO         Canary found          NX enabled    PIE enabled
  gnome-session    1524 Partial RELRO      Canary found          NX enabled    No PIE
    dbus-daemon    1529 Partial RELRO      Canary found          NX enabled    No PIE
          gvfsd    1533 Partial RELRO      No canary found       NX enabled    No PIE
     ibus-dconf    1538 Partial RELRO      No canary found       NX enabled    No PIE
   ibus-ui-gtk3    1539 Partial RELRO      No canary found       NX enabled    No PIE
       ibus-x11    1542 Partial RELRO      Canary found          NX enabled    No PIE
     gvfsd-fuse    1545 Partial RELRO      No canary found       NX enabled    No PIE
at-spi2-registr    1555 Full RELRO         Canary found          NX enabled    PIE enabled
     pulseaudio    1645 Full RELRO         Canary found          NX enabled    No PIE
ibus-engine-sim    1692 Partial RELRO      No canary found       NX enabled    No PIE
       metacity    1775 Partial RELRO      Canary found          NX enabled    No PIE
  dconf-service    1781 Partial RELRO      Canary found          NX enabled    No PIE
    gnome-panel    1819 Partial RELRO      Canary found          NX enabled    No PIE
indicator-appli    1835 Partial RELRO      No canary found       NX enabled    No PIE
unity-fallback-    1836 Partial RELRO      No canary found       NX enabled    No PIE
indicator-bluet    1837 Partial RELRO      No canary found       NX enabled    No PIE
      vmtoolsd     1839 Partial RELRO      Canary found          NX enabled    No PIE
polkit-gnome-au    1841 Partial RELRO      No canary found       NX enabled    No PIE
       nautilus    1848 Partial RELRO      Canary found          NX enabled    No PIE
      nm-applet    1852 Partial RELRO      Canary found          NX enabled    No PIE
        initctl    1853 Full RELRO         No canary found       NX enabled    PIE enabled
indicator-messa    1858 Partial RELRO      No canary found       NX enabled    No PIE
indicator-power    1863 Partial RELRO      No canary found       NX enabled    No PIE
```

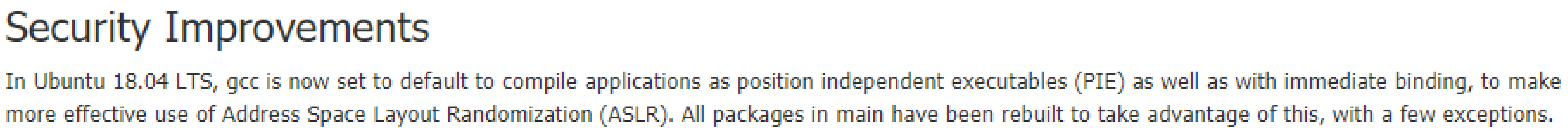
Ubuntu 16.10: PIE everywhere ?!



Built as PIE

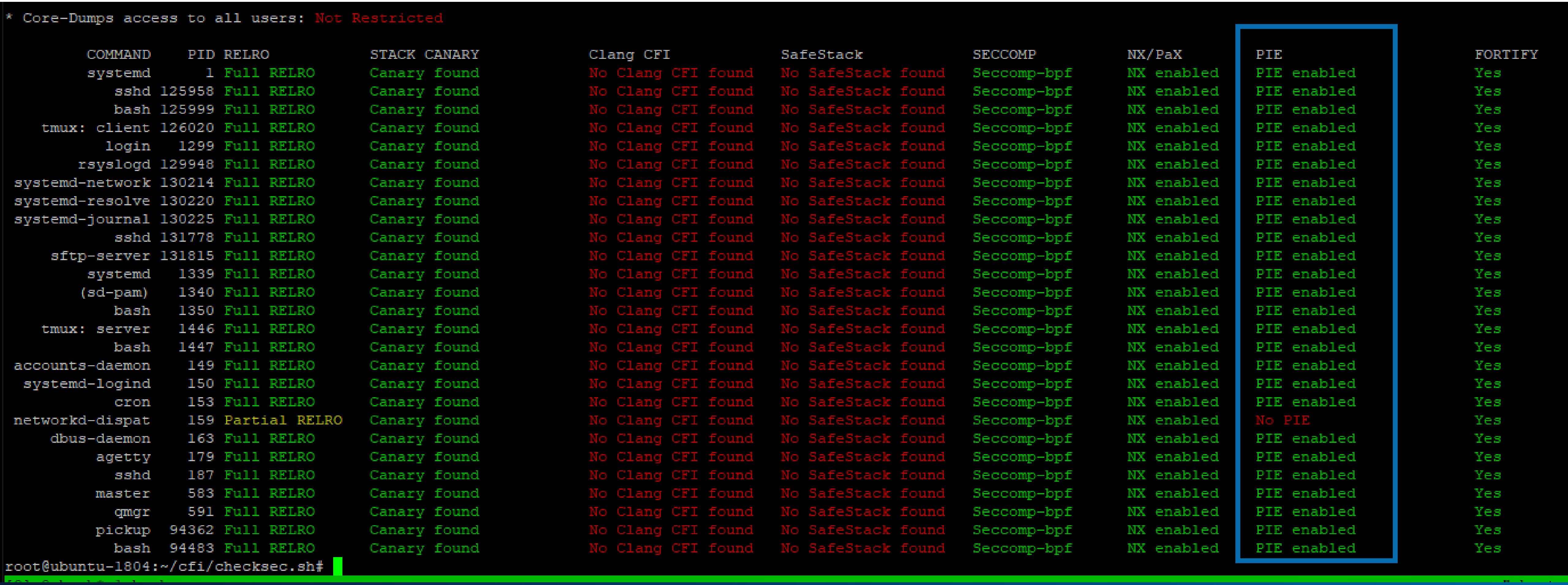
All programs built as Position Independent Executables (PIE) with "-fPIE -pie" can take advantage of the exec ASLR. This protects against "return-to-text" and generally frustrates memory corruption attacks. This requires centralized changes to the compiler options when building the entire archive. PIE has a large (5-10%) performance penalty on architectures with small numbers of general registers (e.g. x86), so it should only be used for a select number of security-critical packages (some upstreams natively support building with PIE, other require the use of "hardening-wrapper" to force on the correct compiler and linker flags). PIE on 64-bit architectures do not have the same penalties, and will eventually be made the default (as of 16.10, it is the default on amd64, ppc64el and s390x).

PIE in Ubuntu



Security Improvements

In Ubuntu 18.04 LTS, gcc is now set to default to compile applications as position independent executables (PIE) as well as with immediate binding, to make more effective use of Address Space Layout Randomization (ASLR). All packages in main have been rebuilt to take advantage of this, with a few exceptions.

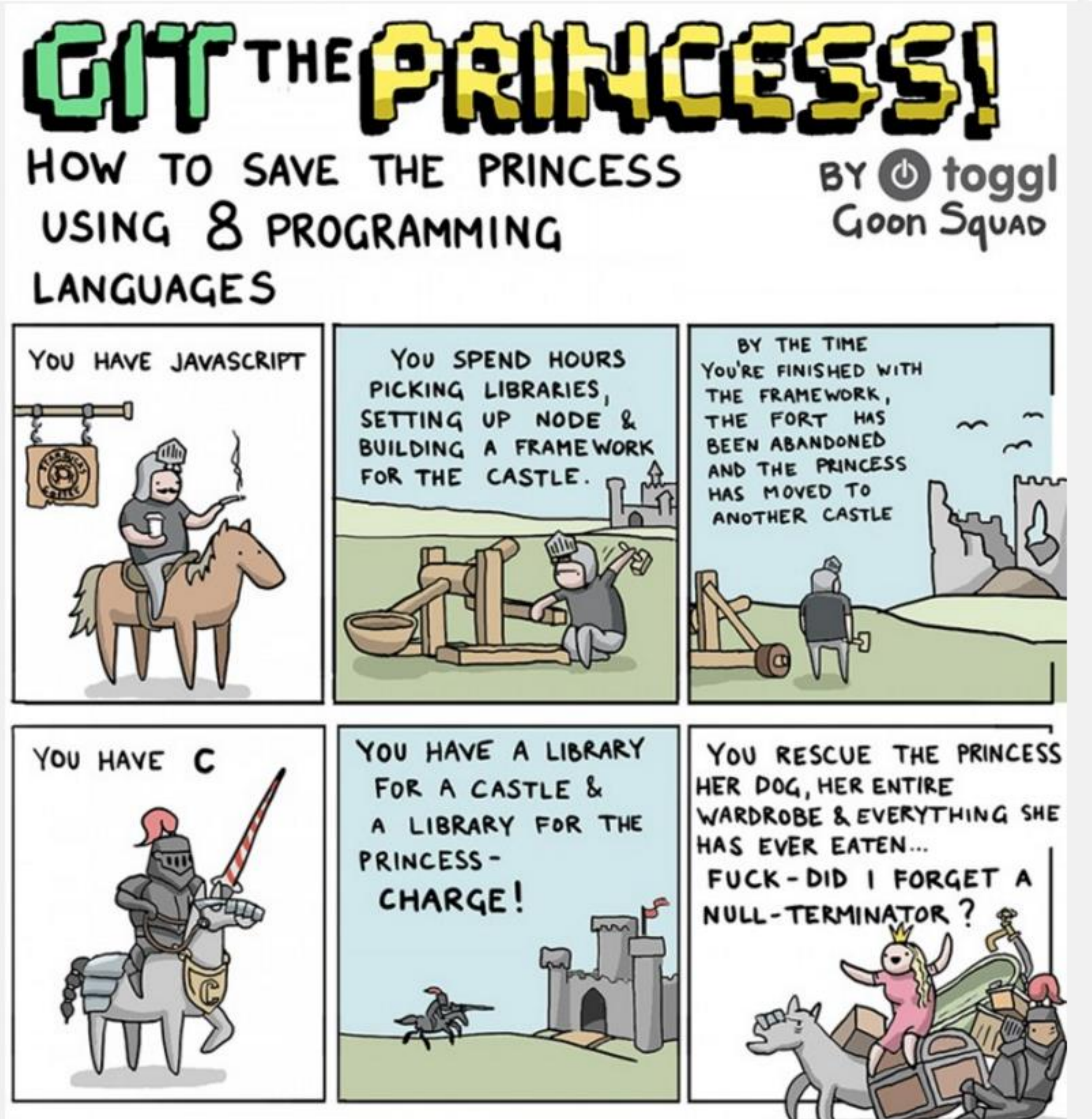


```
* Core-Dumps access to all users: Not Restricted

         COMMAND    PID RELRO           STACK CANARY            Clang CFI            SafeStack            SECCOMP          NX/PaX        PIE                     FORTIFY
         systemd      1 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
            sshd 125958 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
            bash 125999 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
    tmux: client 126020 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
           login   1299 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
        rsyslogd 129948 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
 systemd-network 130214 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
 systemd-resolve 130220 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
 systemd-journal 130225 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
            sshd 131778 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
     sftp-server 131815 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
         systemd   1339 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
        (sd-pam)   1340 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
            bash   1350 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
    tmux: server   1446 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
            bash   1447 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
 accounts-daemon    149 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
  systemd-logind    150 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
            cron    153 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
 networkd-dispat    159 Partial RELRO   Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    No PIE                  Yes
     dbus-daemon    163 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
          agetty    179 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
            sshd    187 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
          master    583 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
            qmgr    591 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
          pickup  94362 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
            bash  94483 Full RELRO      Canary found            No Clang CFI found   No SafeStack found   Seccomp-bpf      NX enabled    PIE enabled             Yes
root@ubuntu-1804:~/cfi/checksec.sh#
```

What is the fundamental difference between attack and defense?

You know when an attack does not work...


GIT THE PRINCESS!
HOW TO SAVE THE PRINCESS USING 8 PROGRAMMING LANGUAGES
BY toggl Goon Squad
YOU HAVE JAVASCRIPT
YOU SPEND HOURS PICKING LIBRARIES, SETTING UP NODE & BUILDING A FRAMEWORK FOR THE CASTLE.
BY THE TIME YOU'RE FINISHED WITH THE FRAMEWORK, THE FORT HAS BEEN ABANDONED AND THE PRINCESS HAS MOVED TO ANOTHER CASTLE
YOU HAVE C
C
YOU HAVE A LIBRARY FOR A CASTLE & A LIBRARY FOR THE PRINCESS - CHARGE!
YOU RESCUE THE PRINCESS HER DOG, HER ENTIRE WARDROBE & EVERYTHING SHE HAS EVER EATEN...
FUCK - DID I FORGET A NULL-TERMINATOR?

Exploit Mitigation Conclusion

Defeat Exploit Mitigations: TL;DR

Enable ALL the mitigations (DEP, ASLR w/PIE, Stack Protector)

- Defeat ALL the mitigations:
  - ROP shellcode as stager to defeat DEP
  - Information leak to defeat ASLR
  - Non stack-based-stack-overflow vulnerability

Recap

Information disclosure can eliminate ASLR protection

Which enables ROP to eliminate DEP

References

References:

- ROP CFI RAP XNR CPI WTF? Navigating the Exploit Mitigation Jungle
  - https://bsidesljubljana.si/wp-content/uploads/2017/02/ropcfirapxnrcpiwtf-rodler-bsidesljubljana2017.pdf