Defeat Exploit Mitigations

Contemporary exploiting

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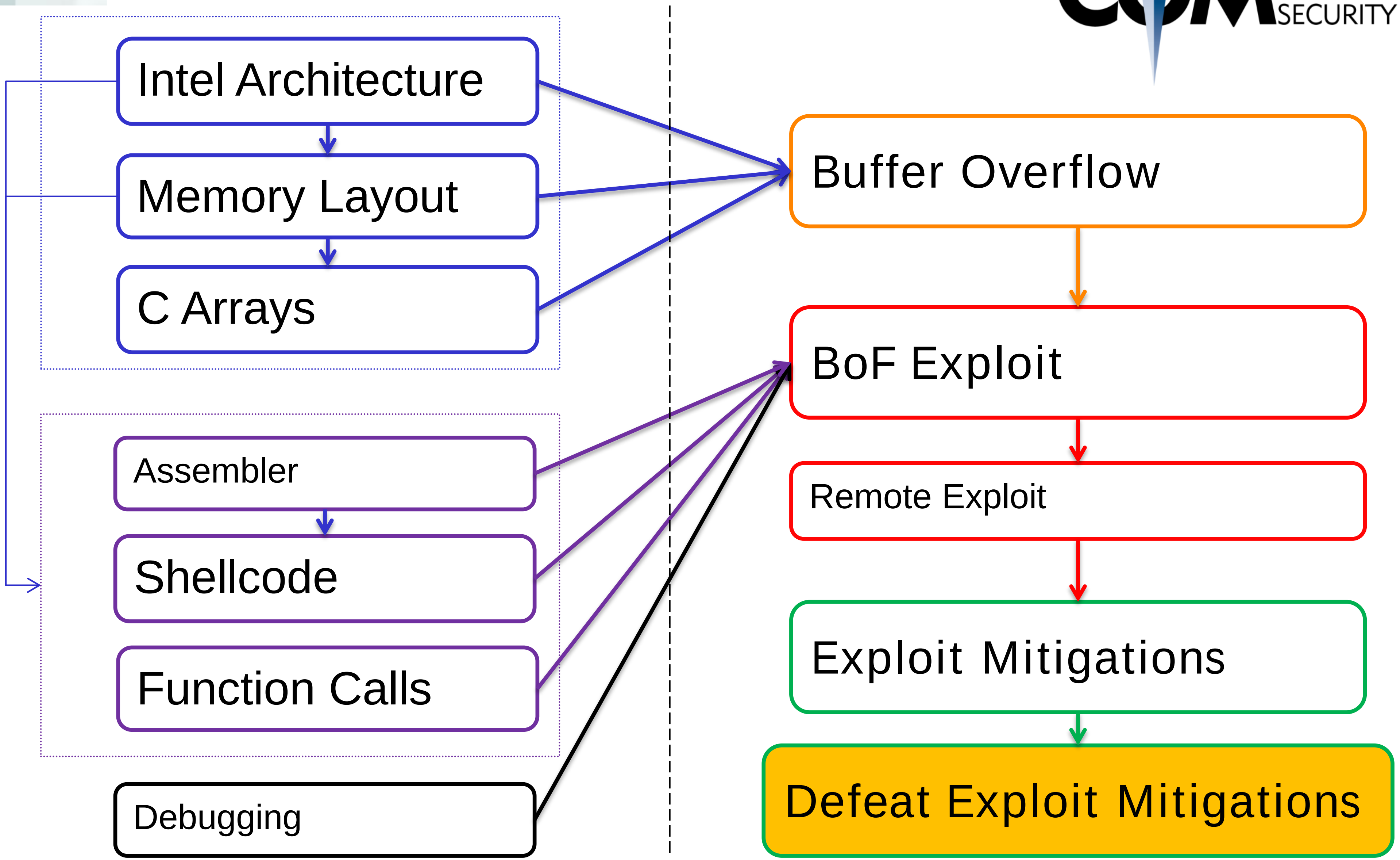
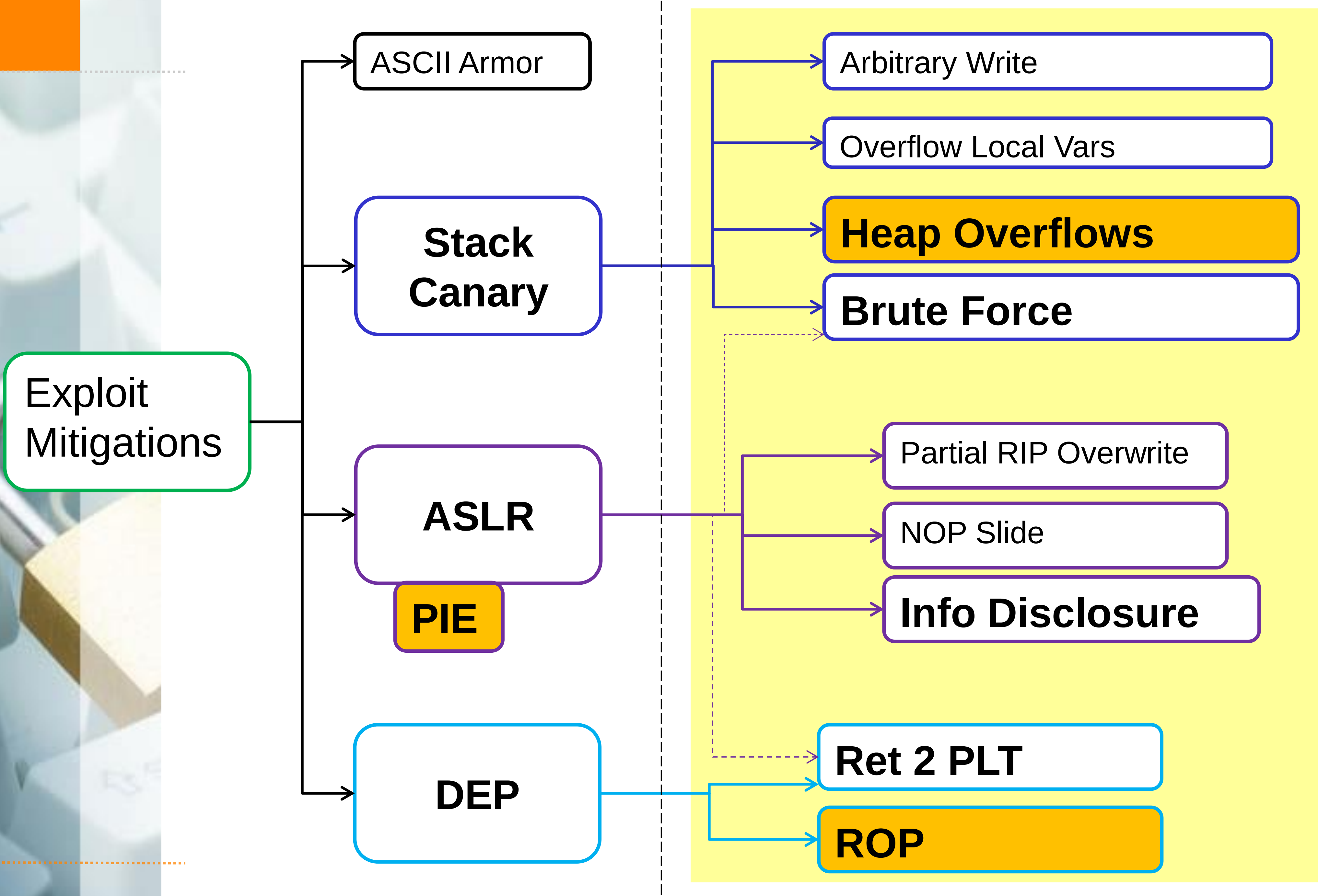
Content


Intel Architecture
Memory Layout
C Arrays
Assembler
Shellcode
Function Calls
Debugging
Buffer Overflow
BoF Exploit
Remote Exploit
Exploit Mitigations
Defeat Exploit Mitigations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ASCII Armor
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Overflow Local Vars
Heap Overflows
Brute Force
Partial RIP Overwrite
NOP Slide
Info Disclosure
Ret 2 PLT
ROP

Anti Exploit Mitigations

Defeat Exploit Mitigations

Stack Canary

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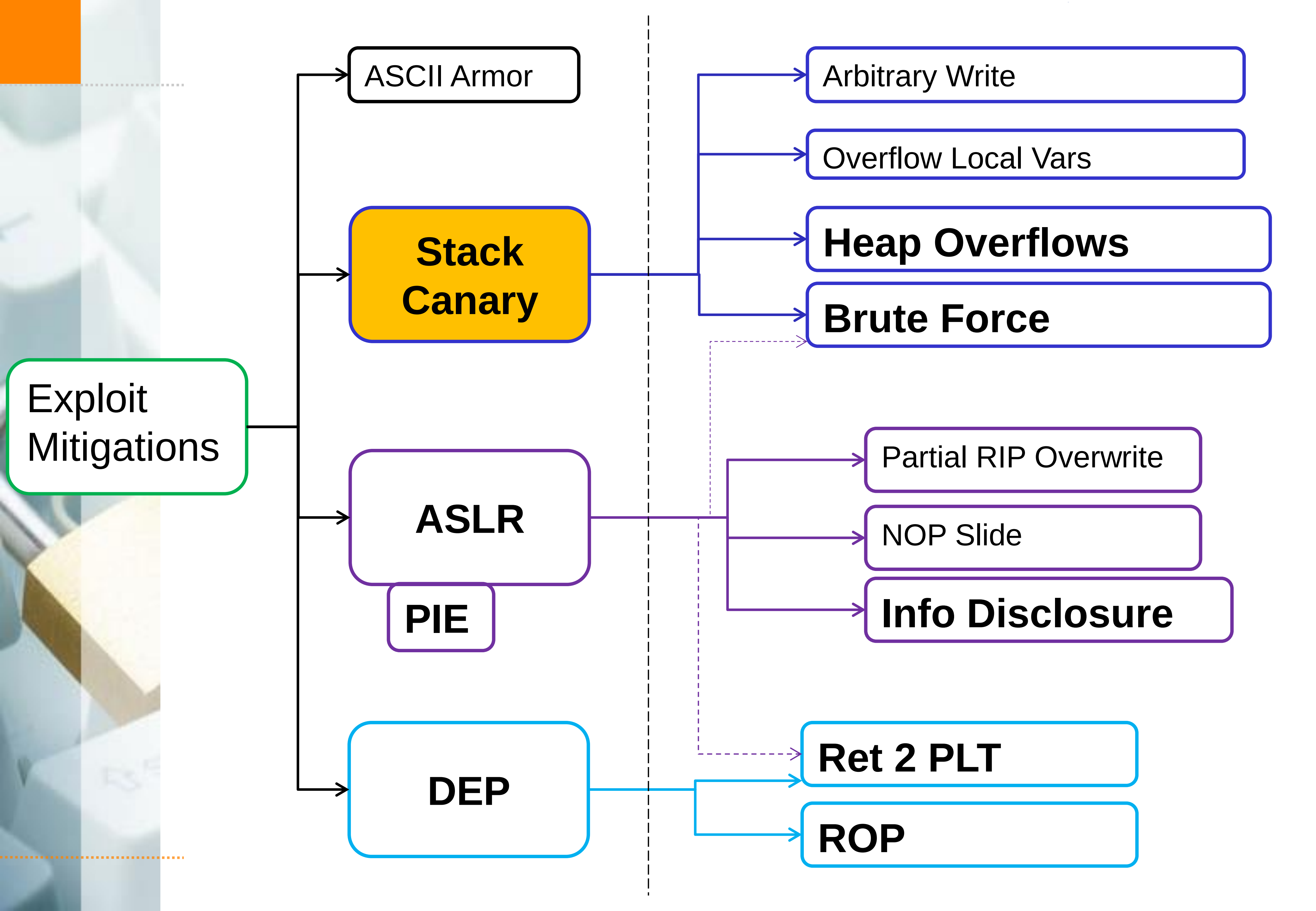

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Recap:

Stack Canary is a secret in front of SBP/SIP

Gets checked upon return()

Prohibits overflows into SIP

Defeating Stack Canary

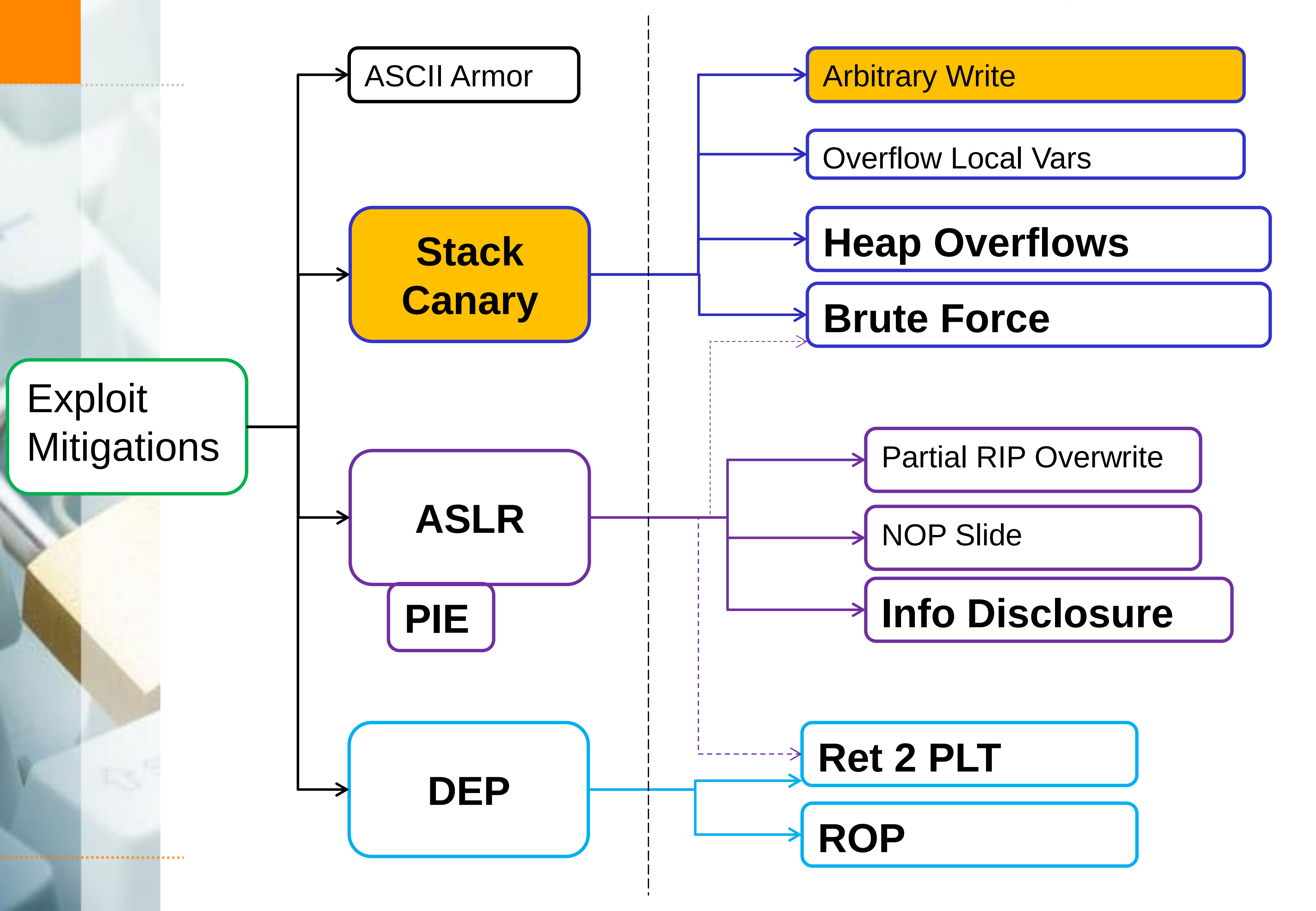
Stack canary protects only **stack overflows into SIP**

e.g:

```
strcpy(a, b);

memcpy(a, b, len);

for(int n=0; n<len; n++) a[n] = b[n]
```



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Defeating Stack Canary: Arb. Write

Arbitrary write:

```
char array[16];
array[userIndex] = userData;
```

- No overflow
- But: write “behind” stack canary

Defeating Stack Canary: Arb. Write

Overwrite SIP without touching the canary:

char **buffer**[64]	canary	SIP
CODE CODE CODE CODE	canary	&buffer

Defeating Stack Canary: Arb. Write

Example: Formatstring attacks

```
userData = "AAAA%204x%n";
```

Skip 204 bytes

Defeating Stack Canary: Arb. Write

Wrong:

```
printf(userData);
```

Correct:

```
printf(“%s”, userData);
```

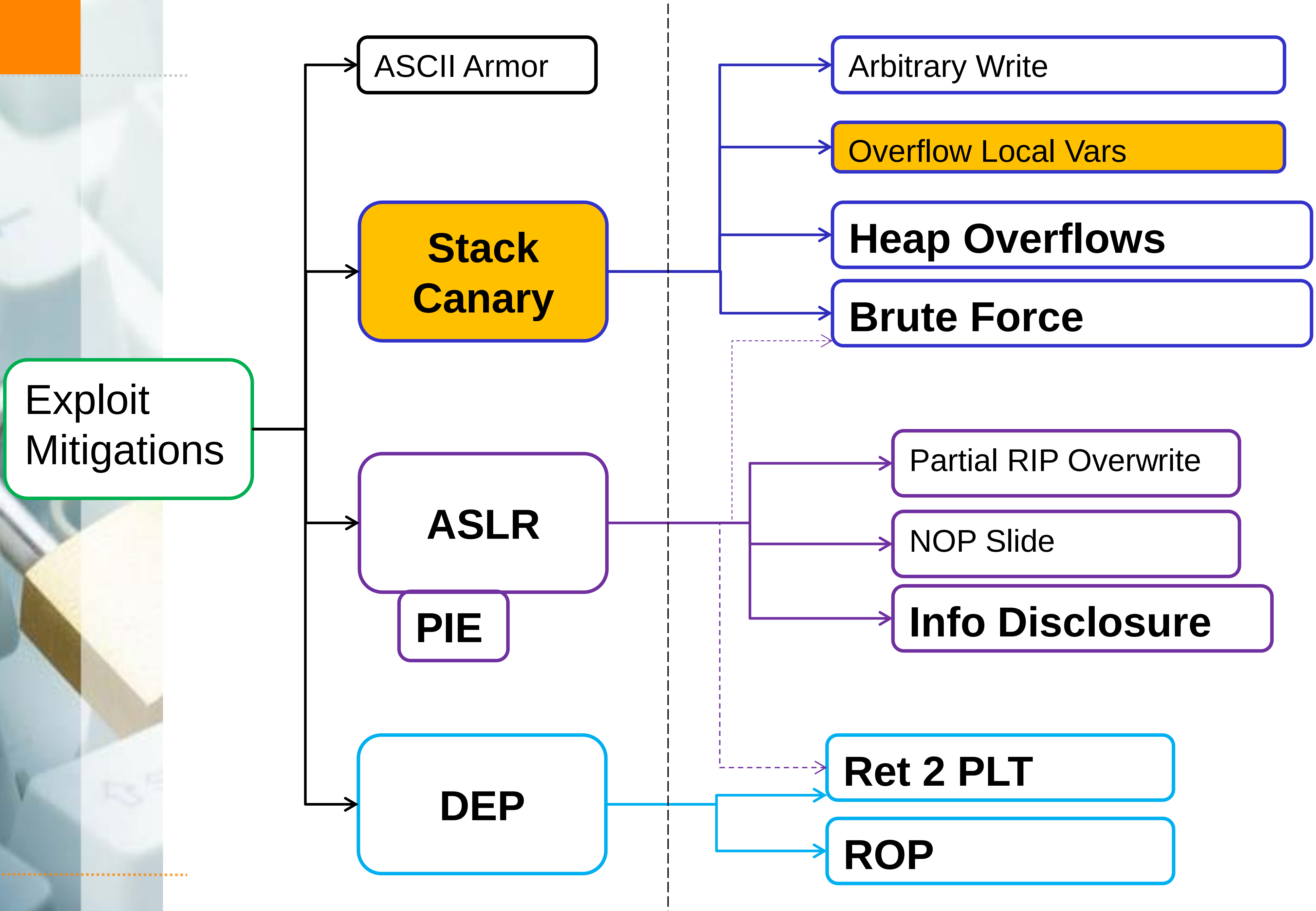
Example: Formatstring attacks

Problem:

- Did not specify format in source
- Problem: %n **writes** data

Nowadays:

- Easy to detect on compile time (static analysis)
- Easy to completely fix (remove %n)
- Nowadays: Not a problem anymore, solved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Defeating Stack Canary: local vars

Stack canary protects metadata of the stack (SBP, SIP, …)

Not protected: **Local variables**

Defeating Stack Canary: local vars

Overwrite local vars:

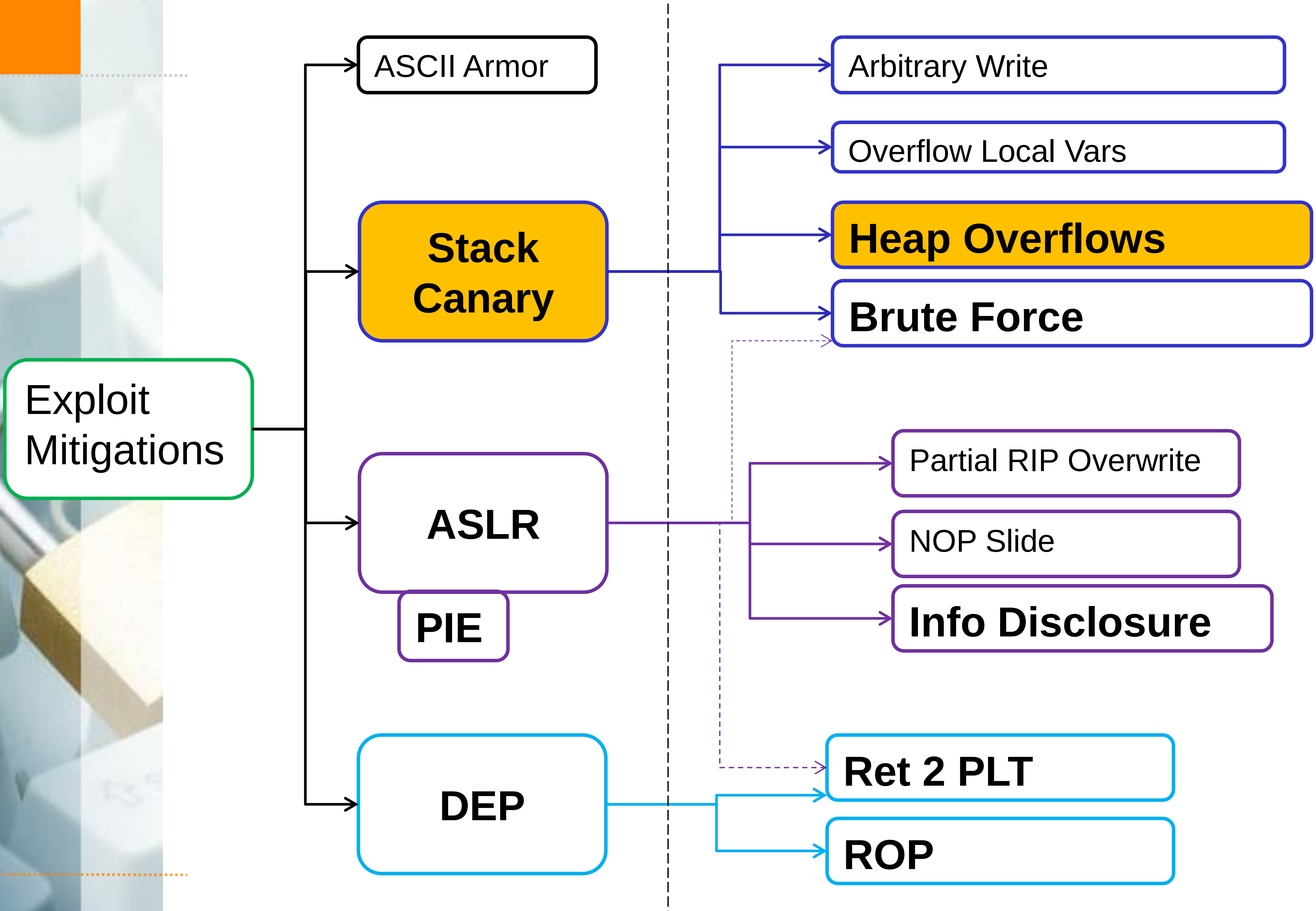
```
{
  void (*ptr)(char *) = &handleData;
  char buf[16];

  strcpy(buf, input);     // overflow
  (*ptr)(buf);            // exec ptr
}
```

Here: Possible to overwrite function pointers

Defeating Stack Canary: Arb. Write

Overwrite a local function pointer:

char **buffer**[64]	*funcPtr	canary	SIP
CODE CODE CODE	&buffer	canary	SIP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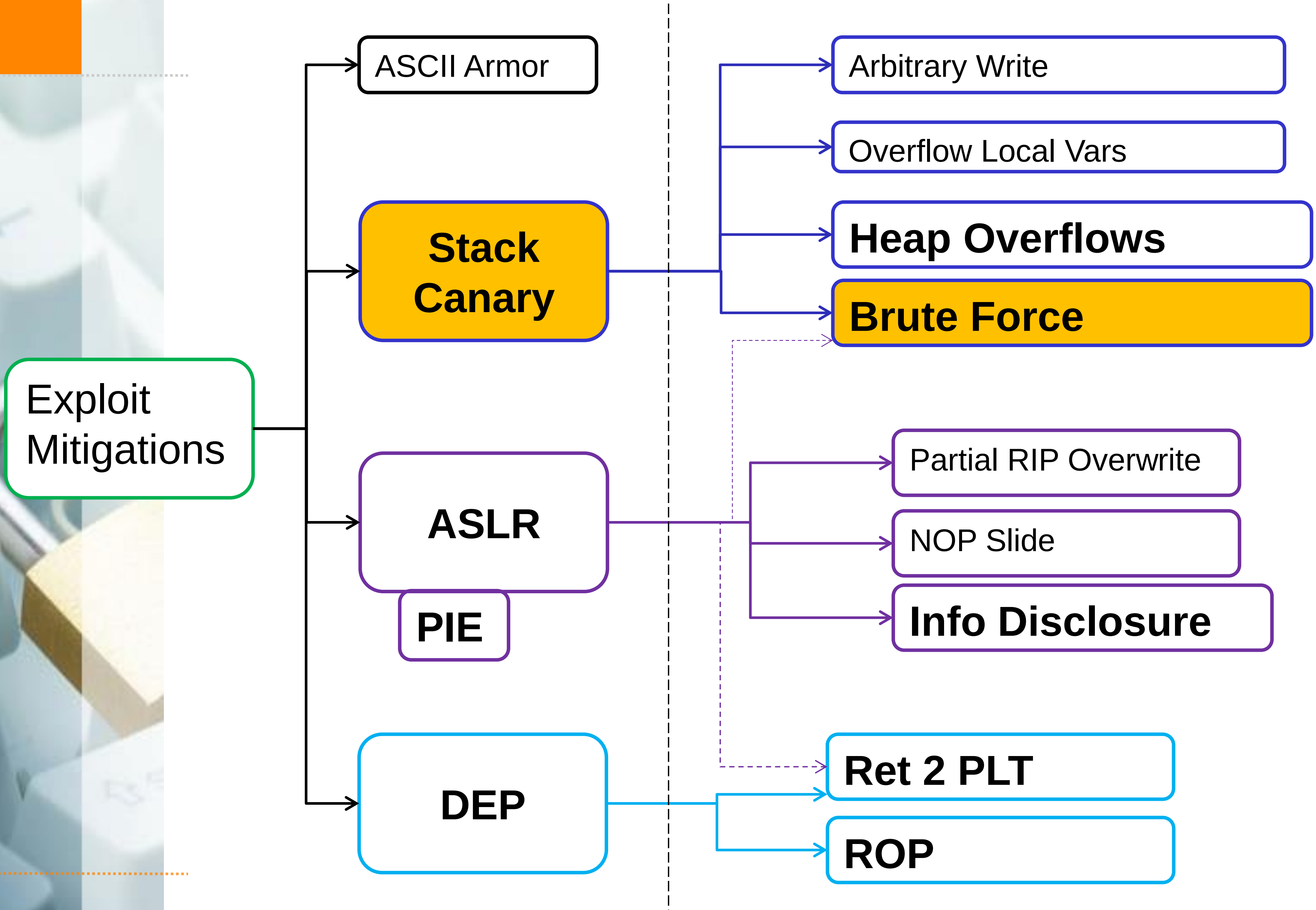
Defeating Stack Canary: heap

Heap is not protected

Heap bug classes:

- Inter-chunck heap overflow/corruption
- Use after free
- Intra-chunk heap overflow / relative write
- Type confusion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Defeating Stack Canary: Brute force

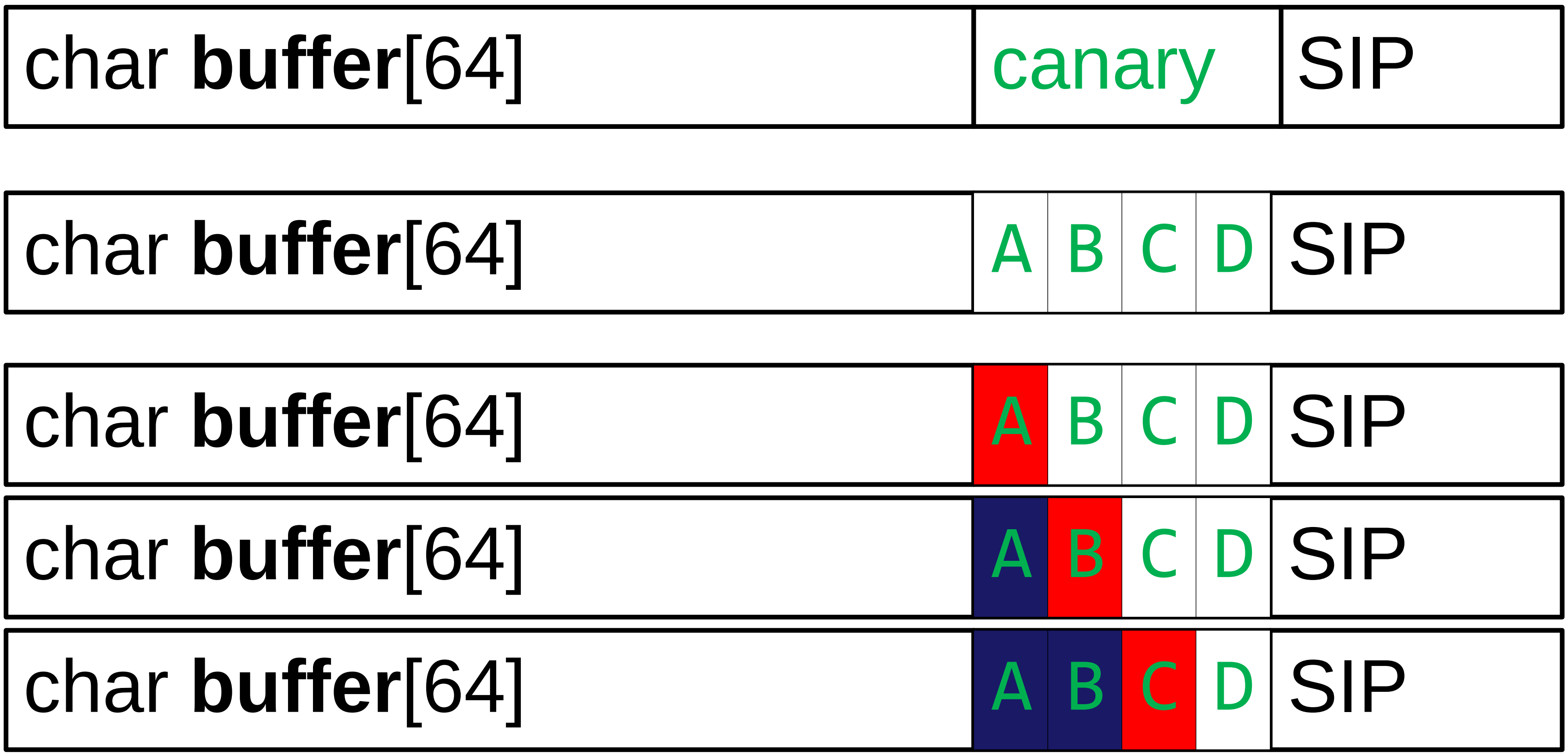
A network server fork()'s again on crash

But stack canary stay's the same

We can brute force it!

- 32 bit value, so 2^32 =~ 4 billion possibilities?

Defeating Stack Canary: Brute force



Defeating Stack Canary: Brute force

Example stack canary: **0xC3B26341**

AAAAAAA	0x41	0x63	0xB2	0xC3	A -> Crash
AAAAAAA	0x42	0x63	0xB2	0xC3	B -> No crash
AAAAAAA	0x42	0x61	0xB2	0xC3	Ba -> Crash
AAAAAAA	0x42	0x62	0xB2	0xC3	Bb -> Crash
AAAAAAA	0x42	0x63	0xB2	0xC3	Bc -> No Crash

Defeating Stack Canary: Brute force

So: not 2^32 = 4 billion possibilities

But:

```
4 * 2^8 =
4 * 256 =
1024 possibilities
```

512 tries (crashes) on average

Defeating Stack Canary: Brute force

I forgot… SFP

Argument for <foobar>

Saved IP (&main)

Saved Frame Pointer

Local Variables <func>

arg1
SIP
SFP
canary
compass1
compass2

Stack Frame <foobar>

push pop

Defeating Stack Canary: Brute force

char **buffer**[64]	canary				SBP				SIP
char **buffer**[64]	A	B	C	D	A	B	C	D	SIP
char **buffer**[64]	A	B	C	D	A	B	C	D	SIP
char **buffer**[64]	A	B	C	D	A	B	C	D	SIP
char **buffer**[64]	A	B	C	D	A	B	C	D	SIP

Defeating Stack Canary: Brute force

Need to break SBP first…

Defeat ASLR for free, because brute force SBP ☺

- (SBP points into stack segment)

Conclusion: Stack Canary:

Can be just **circumvented**

- With the right vulnerability

Or **brute-forced**

- If the vulnerable program is a network server

Recap: Defeating Stack Canary

Defeat Exploit Mitigations

Defeating: DEP

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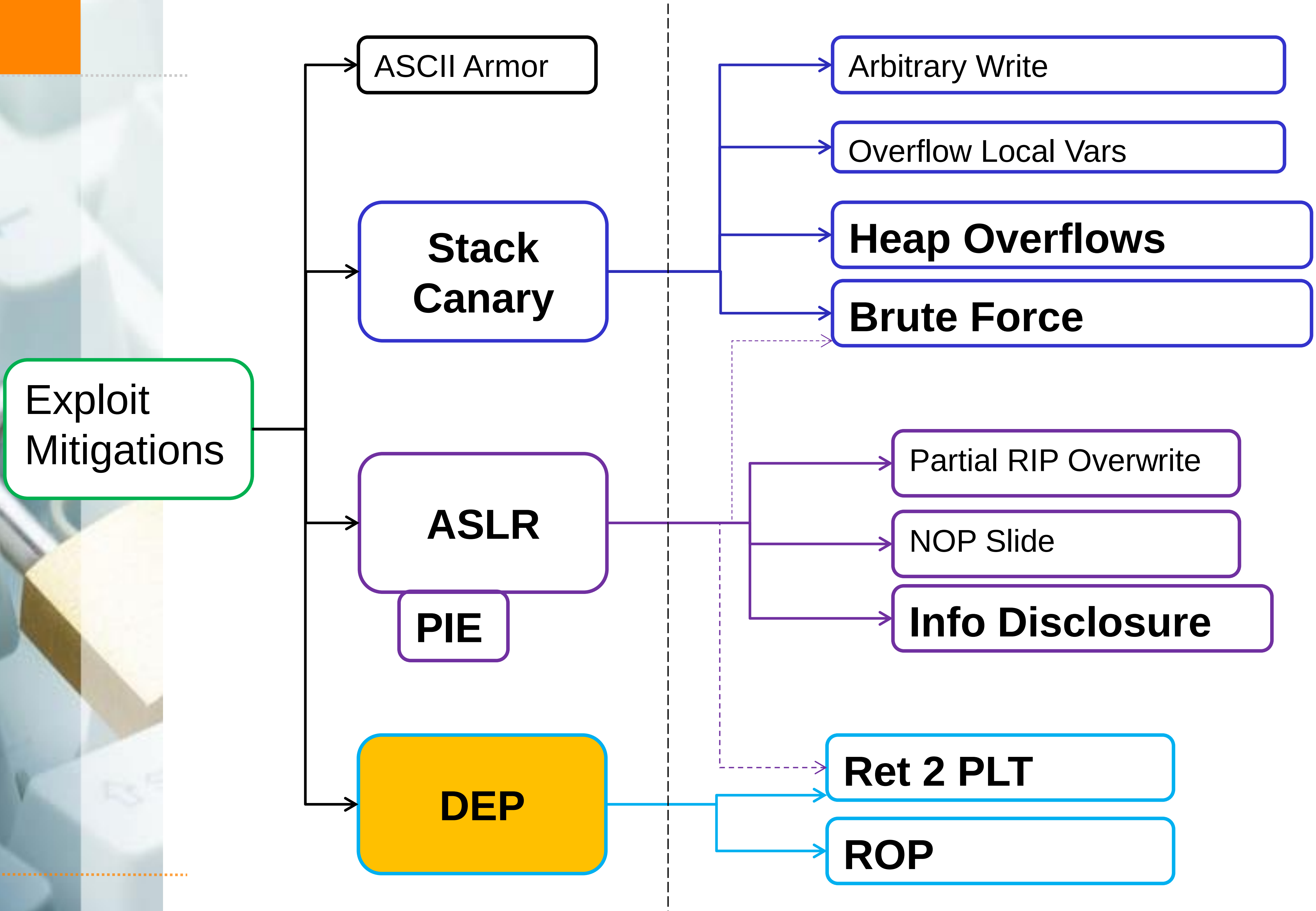
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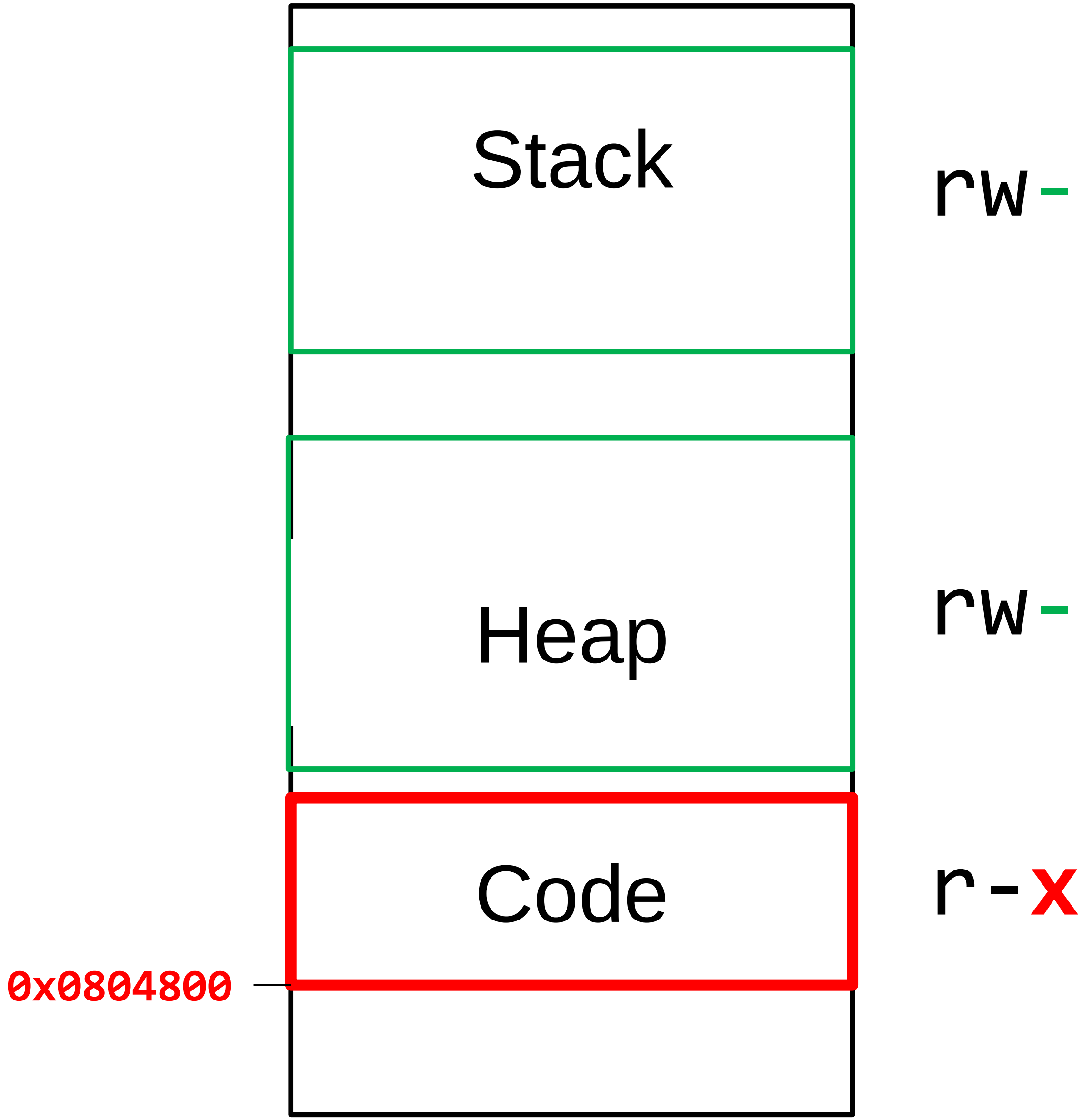
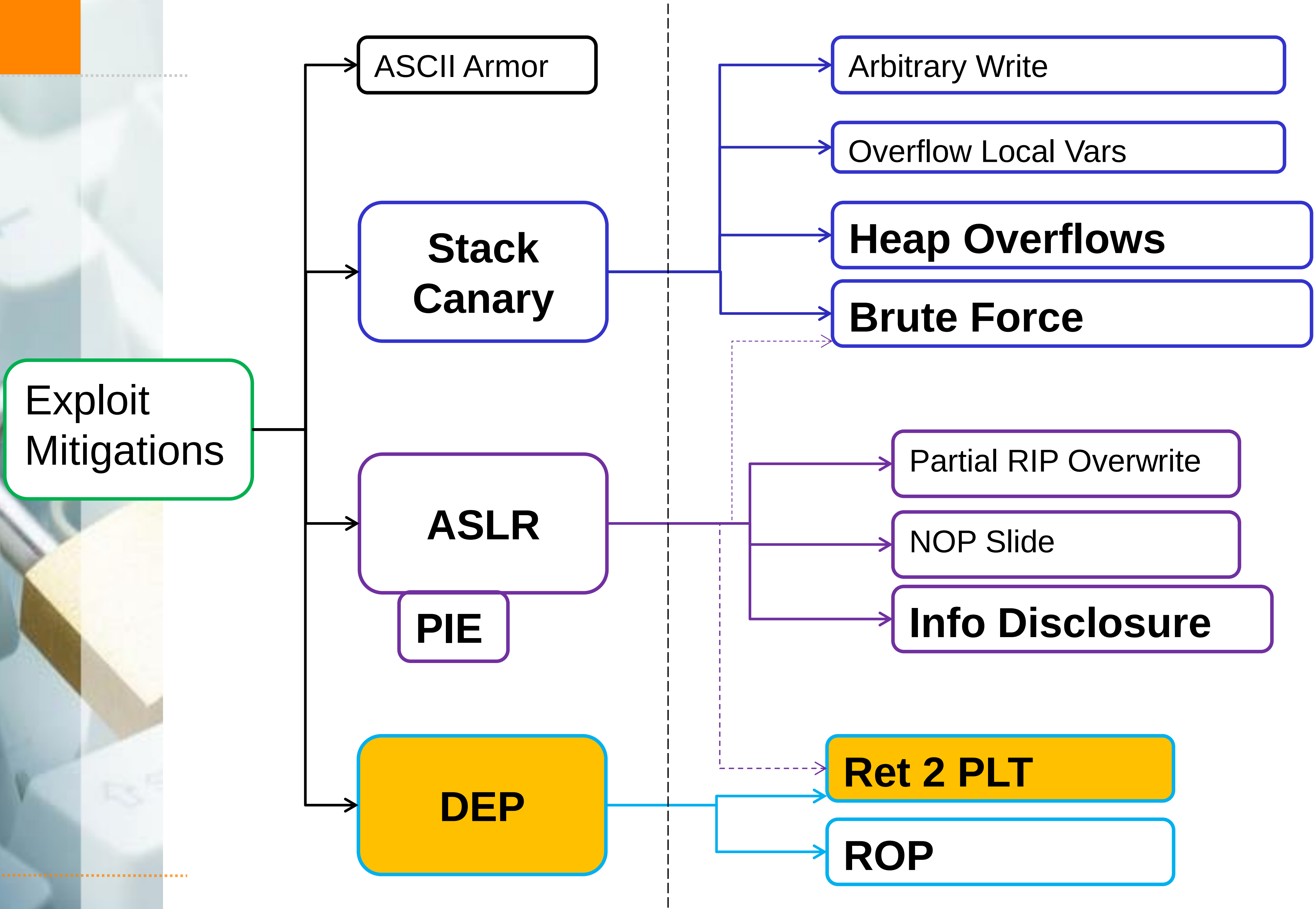
Recap:

DEP makes Stack and Heap non-executable

- Shellcode cannot be executed anymore

Defeating DEP - Intro

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Defeating DEP - Intro

DEP does not allow execution of uploaded code

But what about **existing code**?

- Existing LIBC Functions (ret2plt)
- Existing Code (ROP)

Defeating DEP – Ret2plt

Solution:

- ret2libc / ret2got / ret2plt

Defeating DEP – Ret2plt

Introducing shared libraries

- Like windows DLL's
- Located in /lib and other directories
- Often end in ".so"

- Provide shared functionality
- E.g. libc, openssl, and much more

- Use "ldd" to check shared libraries

Defeating DEP – Ret2plt

```
$ ldd /bin/bash
        linux-gate.so.1 =>  (0xb7724000)
        libtinfo.so.5 => /lib/i386-linux-gnu/libtinfo.so.5 (0xb76f9000)
        libdl.so.2 => /lib/i386-linux-gnu/libdl.so.2 (0xb76f4000)
        libc.so.6 => /lib/i386-linux-gnu/libc.so.6 (0xb754a000)
        /lib/ld-linux.so.2 (0xb7725000)
```

Defeating DEP – Ret2plt

```
$ ldd `which nmap`
        linux-gate.so.1 =>  (0xb777f000)
        libpcap.so.0.8 => /usr/lib/i386-linux-gnu/libpcap.so.0.8
        libssl.so.1.0.0 => /lib/i386-linux-gnu/libssl.so.1.0.0
        libcrypto.so.1.0.0 => /lib/i386-linux-gnu/libcrypto.so.1.0.0
        libdl.so.2 => /lib/i386-linux-gnu/libdl.so.2 (0xb7532000)
        libstdc++.so.6 => /usr/lib/i386-linux-gnu/libstdc++.so.6
        libm.so.6 => /lib/i386-linux-gnu/libm.so.6 (0xb7421000)
        libgcc_s.so.1 => /lib/i386-linux-gnu/libgcc_s.so.1 (0xb7403000)
        libc.so.6 => /lib/i386-linux-gnu/libc.so.6 (0xb7259000)
        libz.so.1 => /lib/i386-linux-gnu/libz.so.1 (0xb7243000)
        /lib/ld-linux.so.2 (0xb7780000)
```

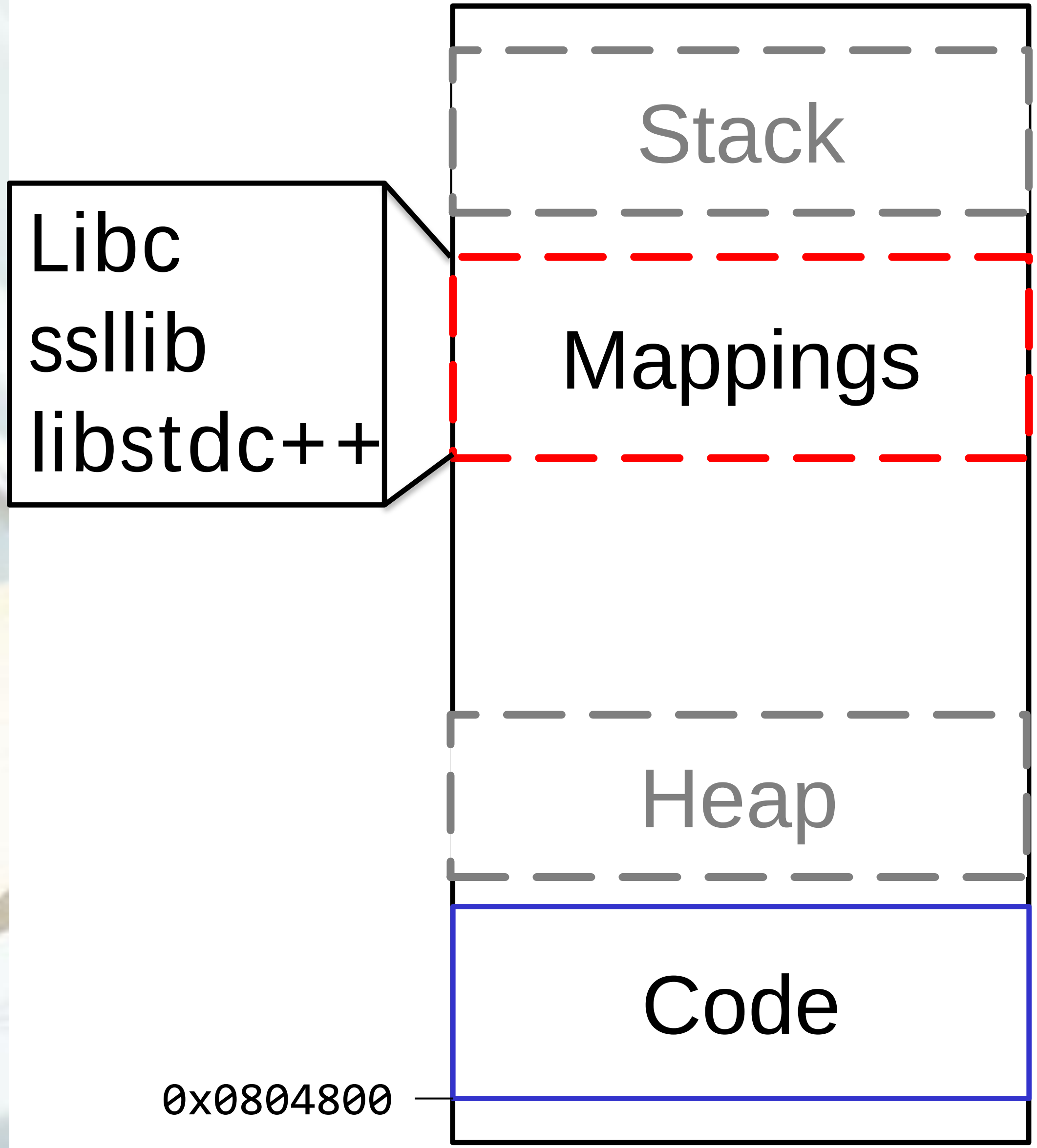
Shared Library Properties

- Shared libraries reference a certain version of a library

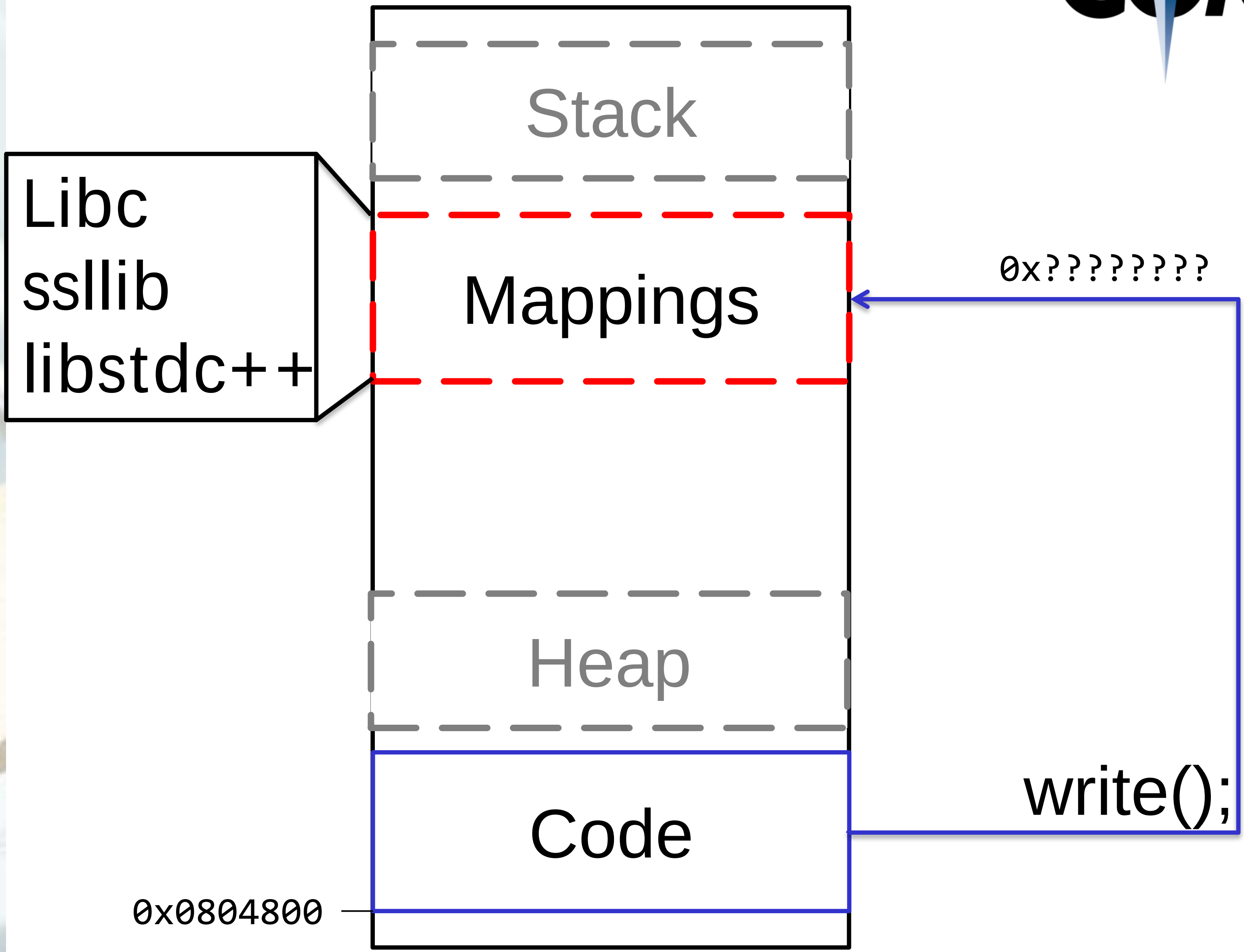
- Shared libraries can:
  - Be updated (grow in size)
  - Load in arbitrary order

- Therefore: Unknown exact location of shared library in memory space!

Defeating DEP – Ret2plt



Defeating DEP – Ret2plt



Defeating DEP – Ret2plt

Call's in ASM are ALWAYS to absolute addresses

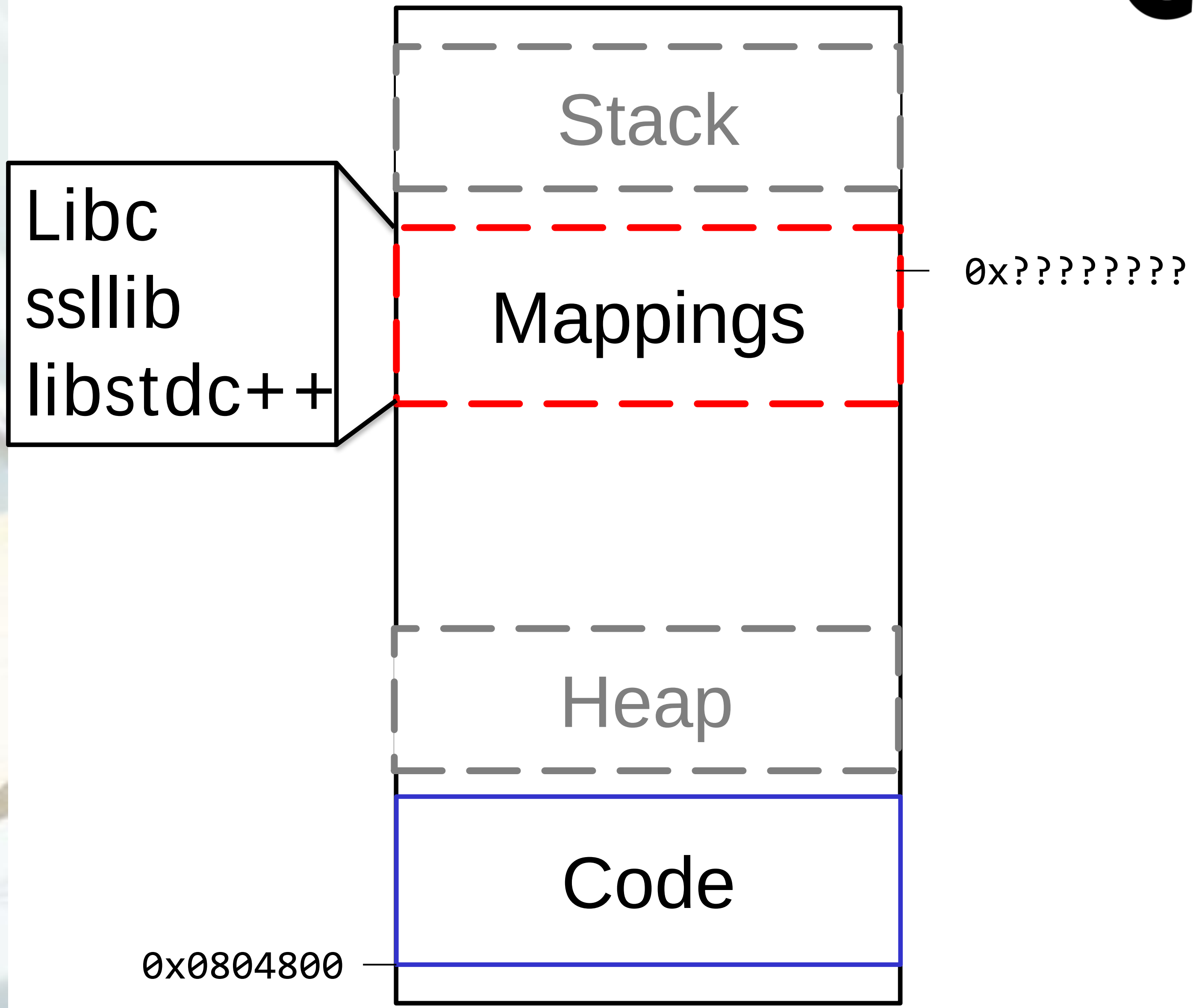
```
e8 d5 38 fd ff          call    805e4c0 <strlen@plt>
```

How does it work with dynamic addresses for shared libraries?

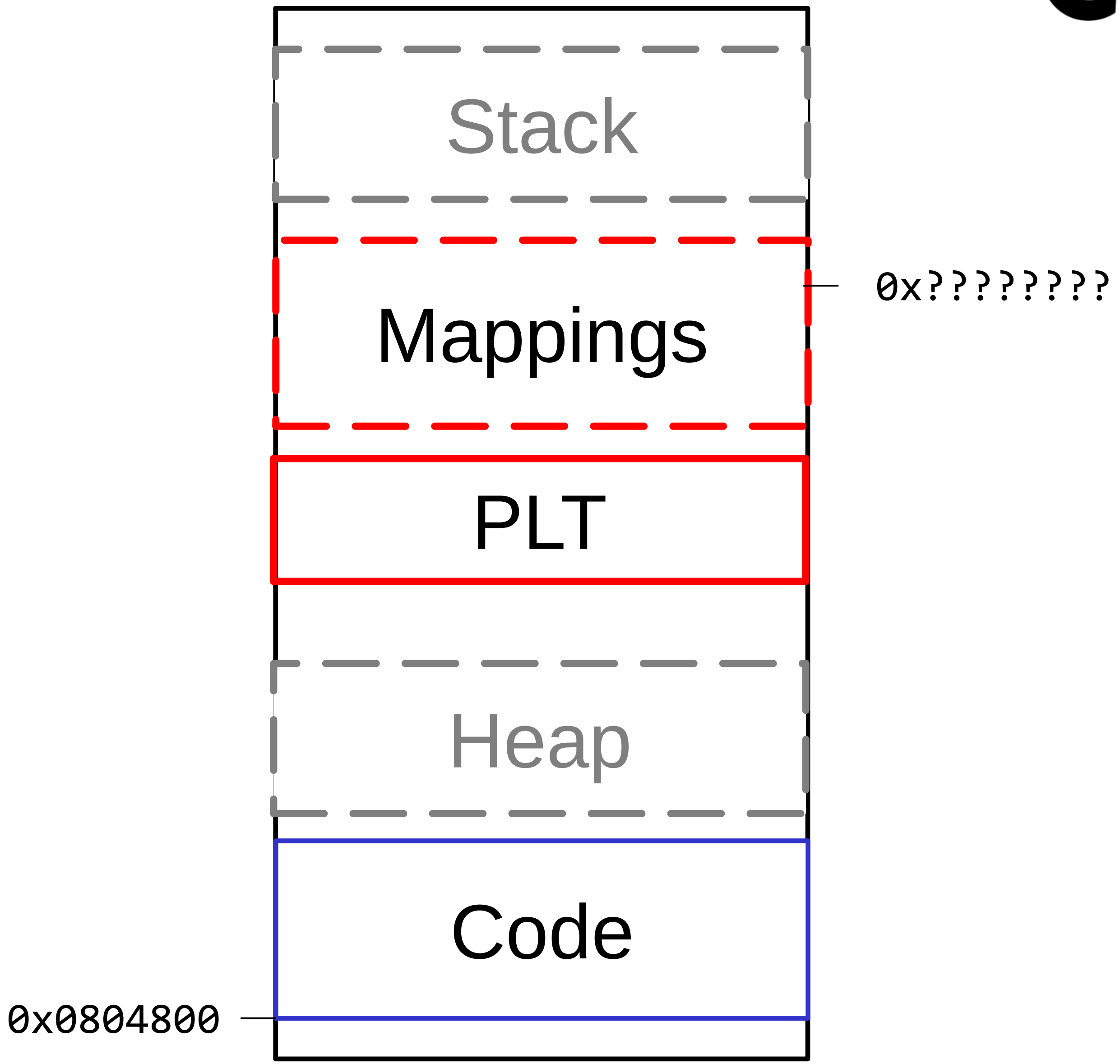
Solution:

- A "helper" at a static location
- In Linux: PLT+GOT (they work together in tandem)

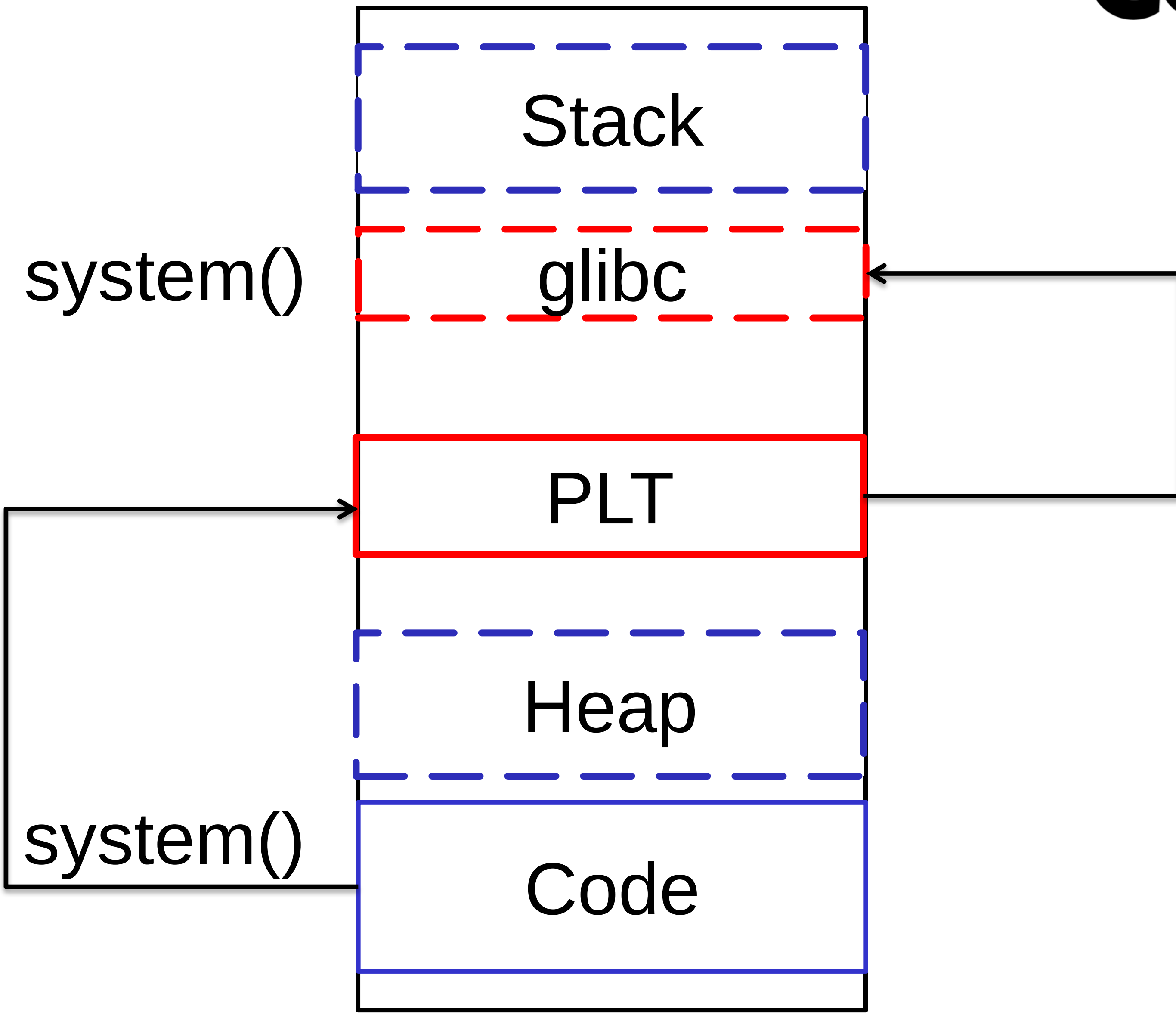
Defeating DEP – Ret2plt



Defeating DEP – Ret2plt



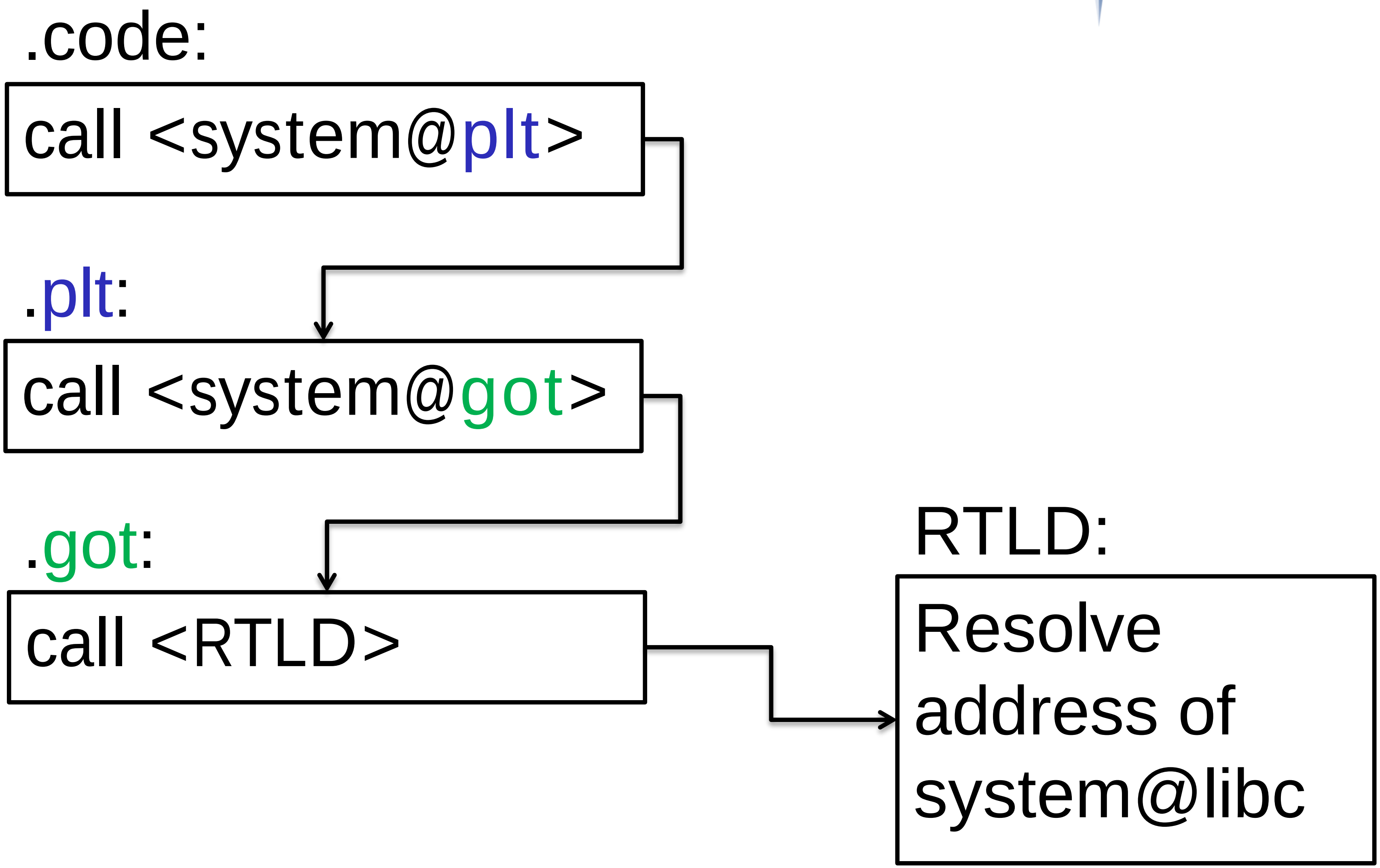
Defeating DEP – Ret2plt



How does it work?

- "call system" is actually "call system@plt"
- The PLT resolves system@libc at runtime
- The PLT stores system@libc in system@got

Defeating DEP – Ret2plt



Defeating DEP – Ret2plt

.code:

call <system@plt>

.plt:

call <system@got>

.got:

call <system@libc>

Write system@libc

RTLD:

Resolve address of system@libc

Defeating DEP – Ret2plt

.code:

call <system@plt>

.plt:

call <system@got>

.got:

call <system@libc>

system@libc:

[Code]

Defeating DEP – Ret2plt

Before executing system():

```
gdb-peda$ print &system
$1 = 0x8048300 <system@plt>
```

After executing system():

```
gdb-peda$ print &system
$2 = 0xb7e67060 <system>    @libc
```

Defeating DEP – Ret2plt

Before executing system():

```
gdb-peda$ print &system
$1 = 0x8048300 <system@plt>
```

After executing system():

```
gdb-peda$ print &system
$2 = 0xb7e67060 <system>    @libc
```

```
Program Headers:
  Type           Offset   VirtAddr   Flg Align
  PHDR           0x000034 0x08048034 R E 0x4
  INTERP         0x000154 0x08048154 R   0x1
  LOAD           0x000000 0x08048000 R E 0x1000
  LOAD           0x000f14 0x08049f14 RW  0x1000

02     .interp .note.ABI-tag .note.gnu.build-id .gnu.hash .dynsym .dynstr
.gnu.version .gnu.version_r .rel.dyn .rel.plt .init .plt .text .fini .rodata
.eh_frame_hdr .eh_frame
```

Defeating DEP – Ret2plt

Before executing system():

```
gdb-peda$ print &system
$1 = 0x8048300 <system@plt>
```

After executing system():

```
gdb-peda$ print &system
$2 = 0xb7e67060 <system>    @libc
```

```
$ cat /proc/31261/maps
…
b7e27000-b7e28000 rw-p 00000000 00:00 0
b7e28000-b7fcb000 r-xp 00000000 08:02 672446     /lib/i386-linux-gnu/libc-2.15.so
b7fcb000-b7fcd000 r--p 001a3000 08:02 672446     /lib/i386-linux-gnu/libc-2.15.so
…
```

Conclusion:

- LIBC interface is stored at a **static location**
- Can jump to system() at known location to execute arbitrary code
- No need for shellcode on stack or heap

Exploiting: DEP – Ret2plt

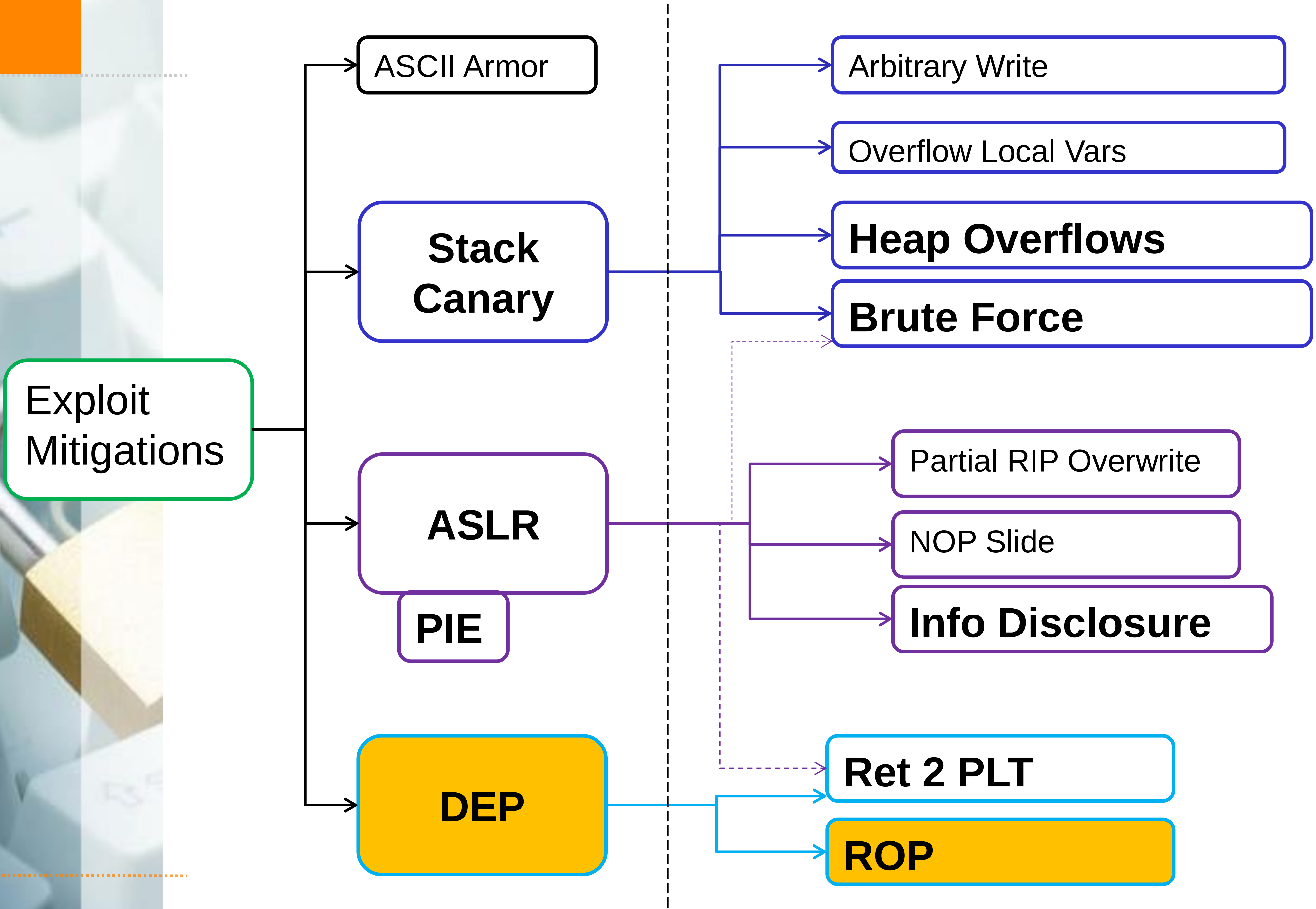
ret2plt

- Defeats DEP

EIP = &system@plt

arg = &meterpreter_bash_shellcode

system("/bin/bash nc –l –p 31337")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ROP

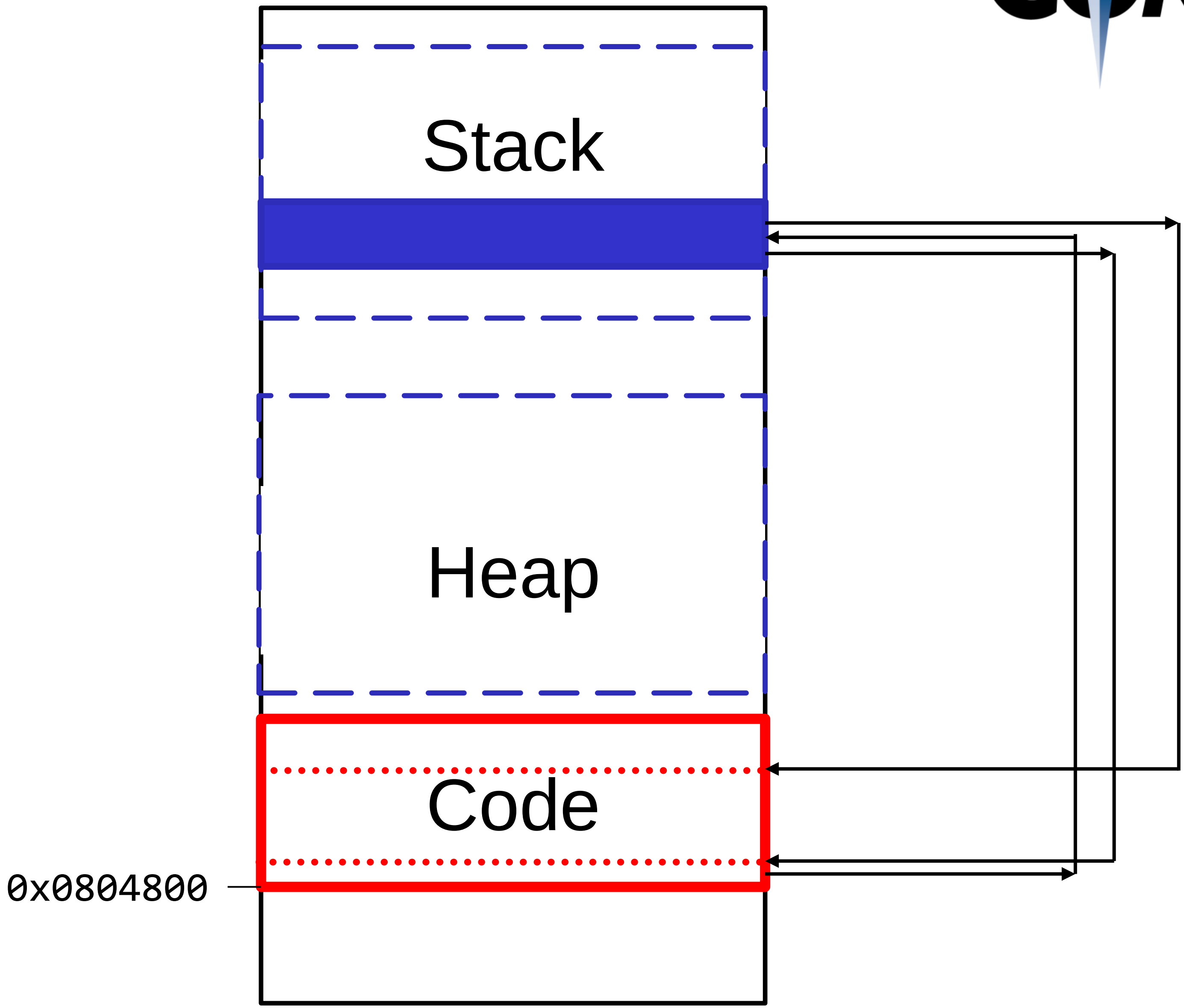
- Extension of "return to libc"
- "Borrowed Code Junks"
- Code from binary, followed by a RET
- Called "gadgets"
- Return Oriented Programming (ROP)

So, what is ROP?

- Code sequence followed by a “ret”

```
pop r15 ; ret
add byte ptr [rcx], al ; ret
dec ecx ; ret
```

Defeating DEP - ROP



Defeating DEP - ROP

Conclusion:

Code section is not randomized

Just smartly re-use existing code

We'll have a look at it later

Defeat Exploit Mitigations: ASLR

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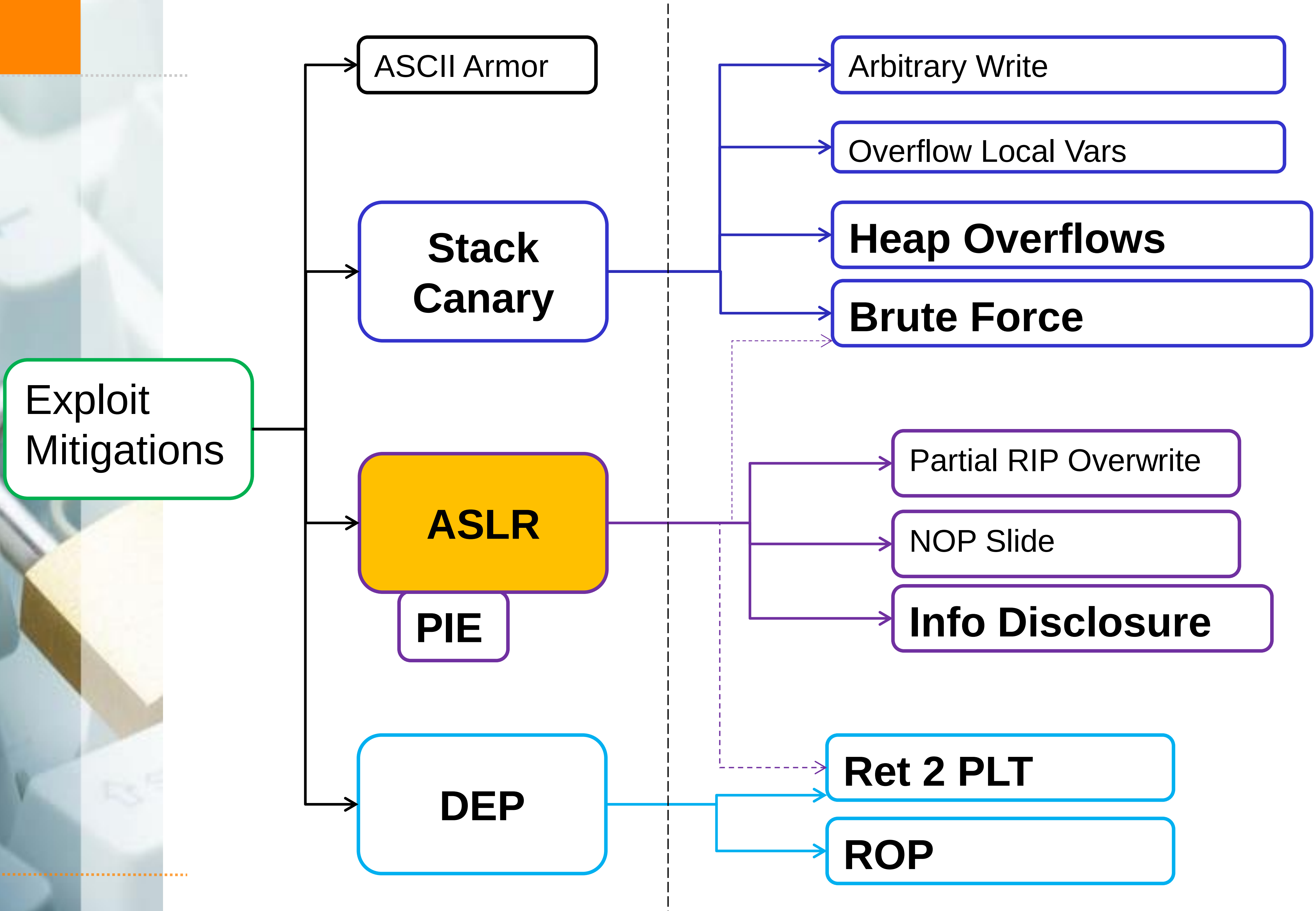

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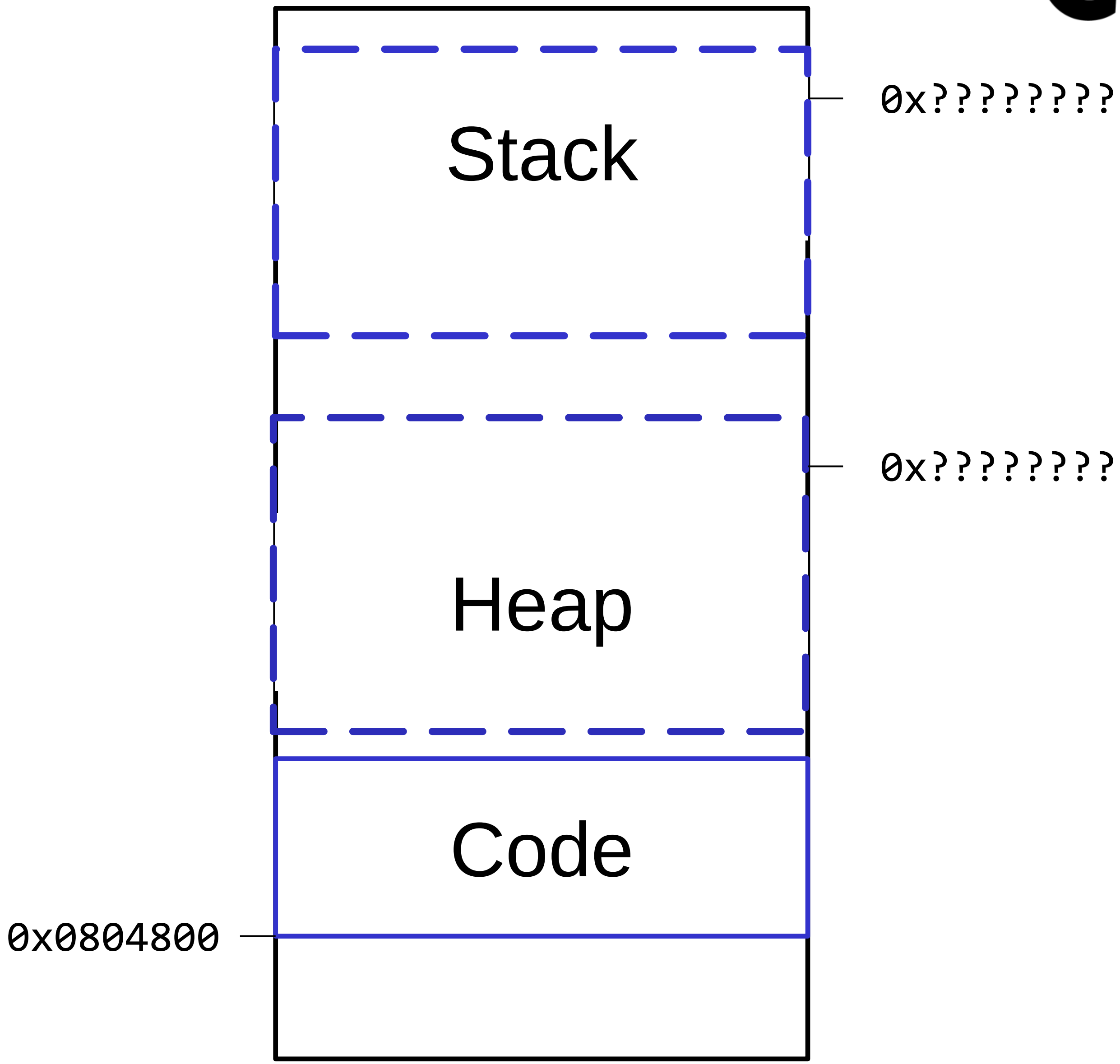
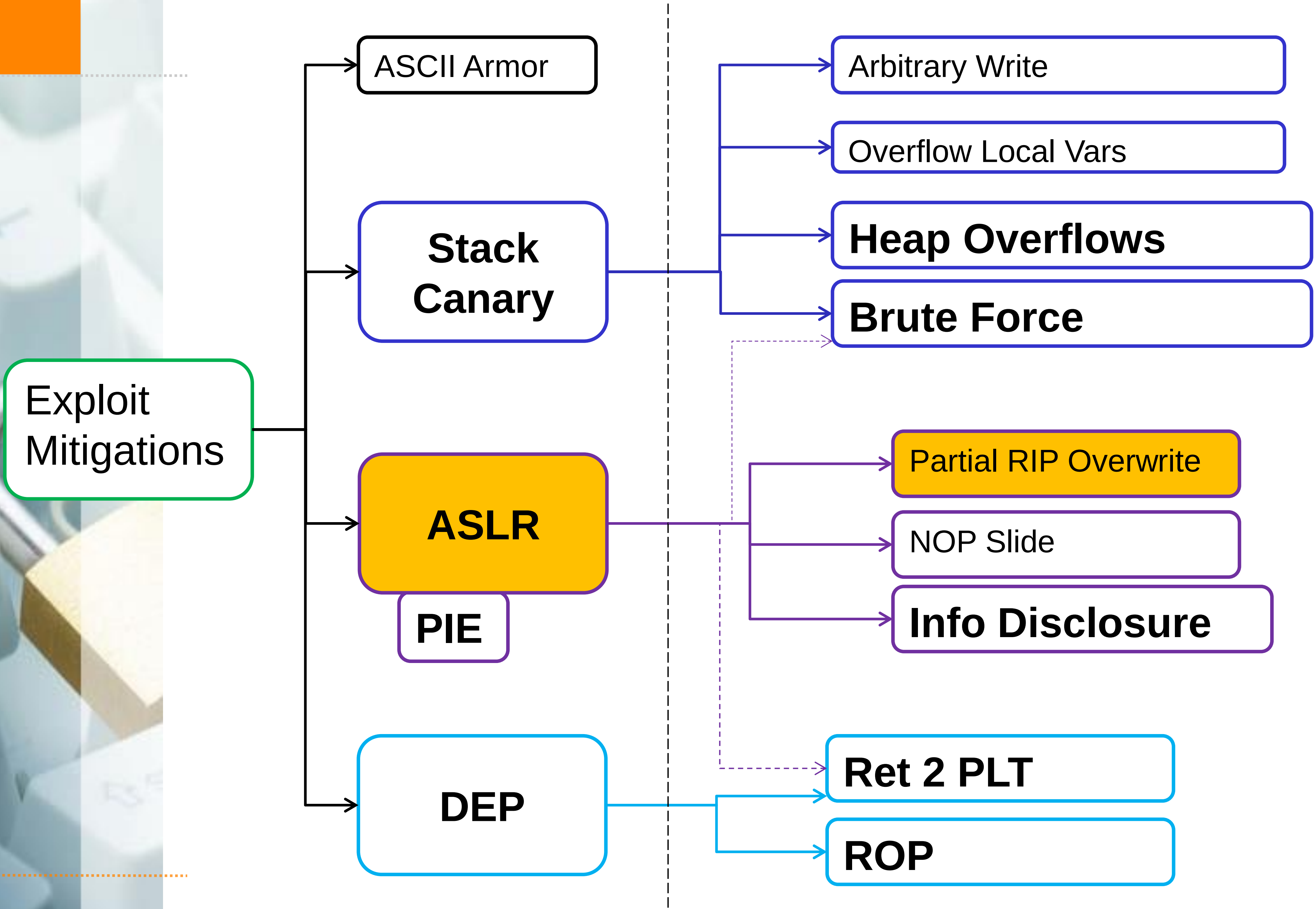
Recap:

ASLR map's Stack & Heap at random locations

Defeating ASLR - Intro





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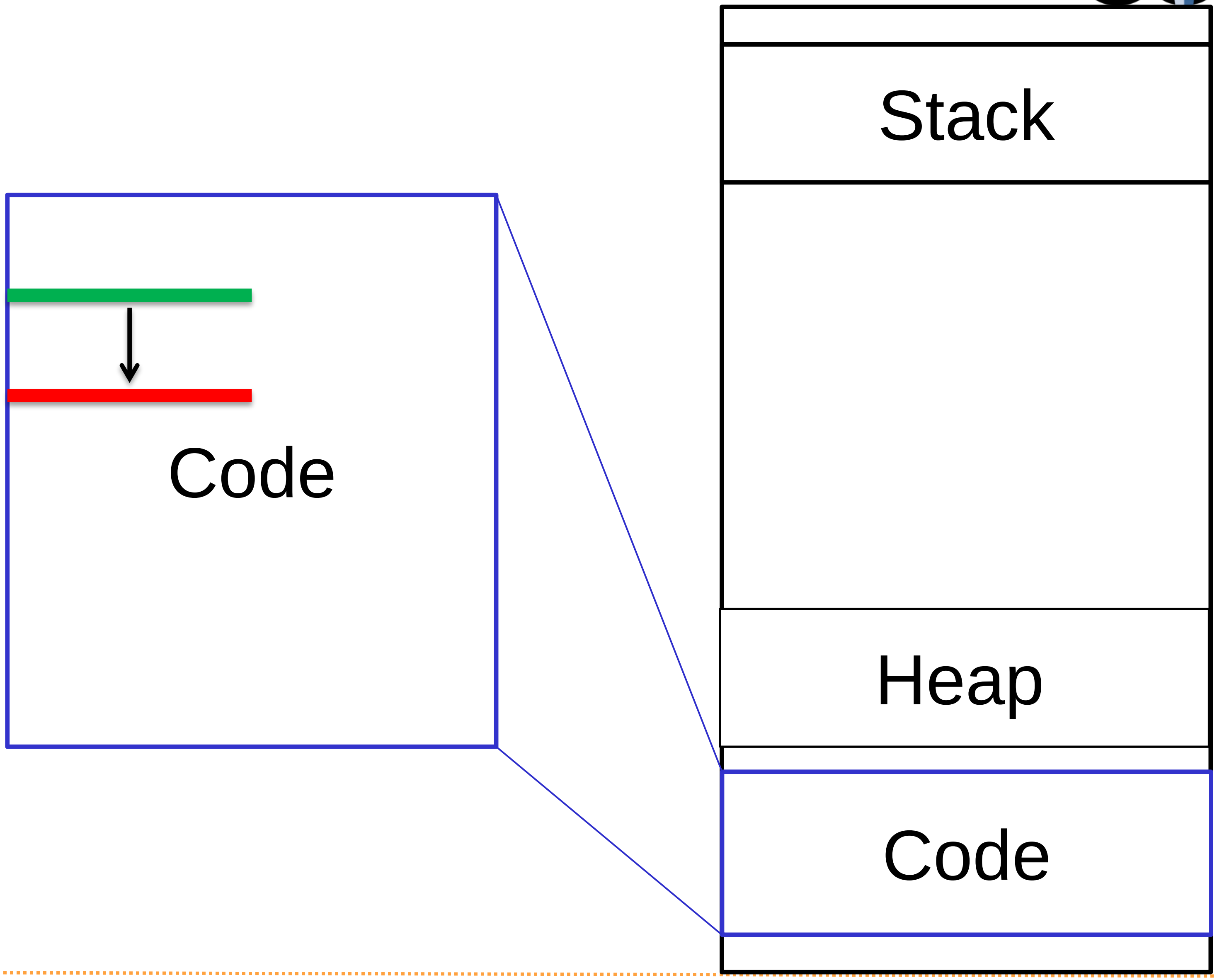
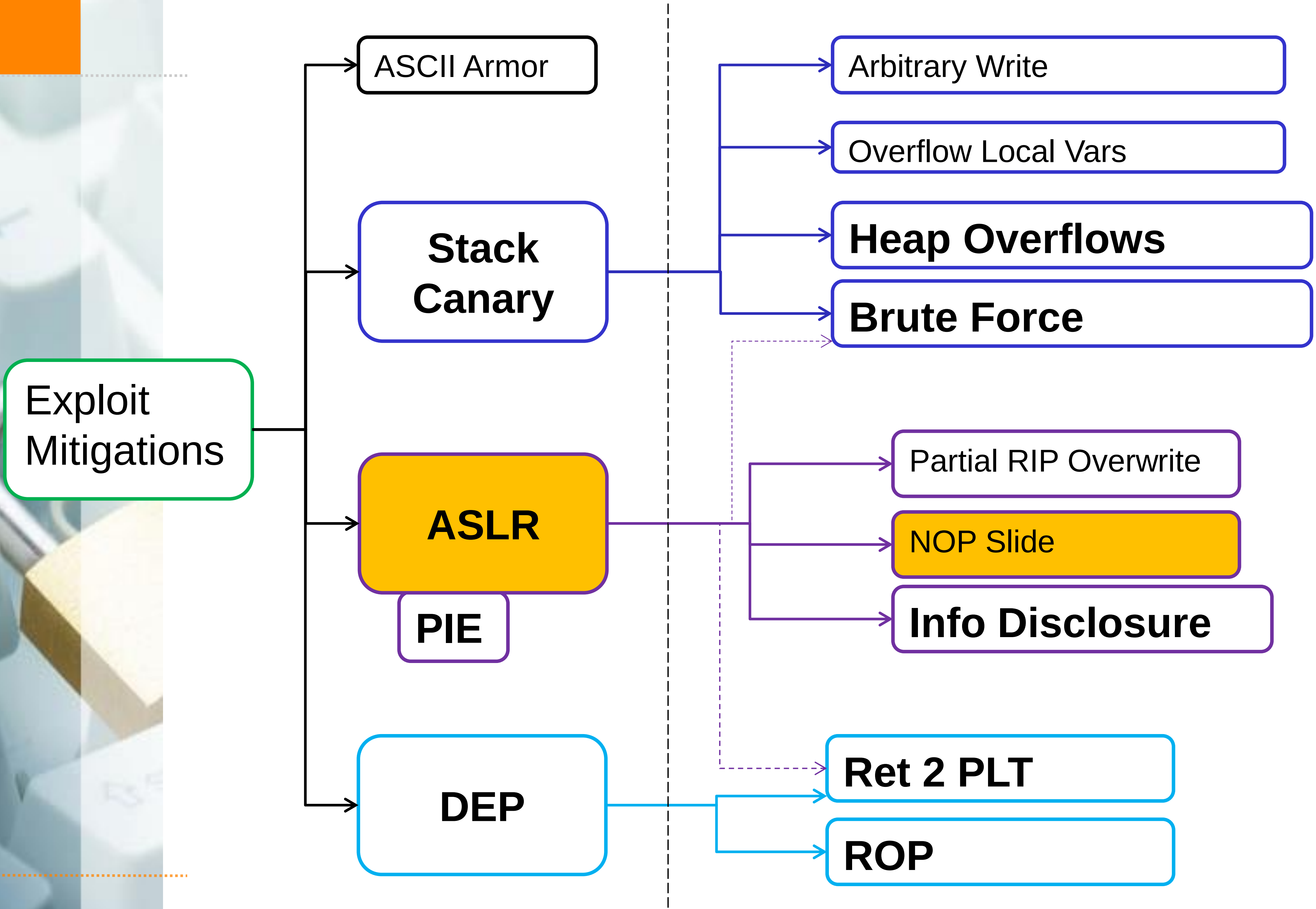
Partial RIP overwrite

- little endianness: **0x11223344**

buf	44	33	22	11	→	func1
buf	52	33	22	11	→	func2

Defeating ASLR – Partial overwrite

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Defeating ASLR – NOP sleds

NOP sleds

- As often used with JavaScript
- **Heap spray** a few megabytes…

NOP NOP NOP NOP NOP … CODE

Anti-ASLR:

- Find static locations (like PLT)
- Mis-use existing pointers
- Spray & Pray

Conclusion

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Defeat Exploit Mitigations - Conclusion

Three default Exploit Mitigations:

- Stack Canary (forbid overflow)
- ASLR (make memory locations unpredictable)
- DEP (make writeable memory non-executable)

There are several techniques which circumvent these Exploit Mitigations

Advanced Exploitation Techniques

Stack-Protector?

- Arbitrary write
- Byte-wise stack-protector brute-force
- Heap Overflow

No-Exec Stack?

- Return to LIBC
- Return to PLT (my favorite ;-))
- ROP

ASLR/PIE?

- Brute Force
  - 12 bit entropy for 32 bit
  - byte-wise brute force
- ROP
- Information Disclosure
- Pointer re-use

Advanced Techniques

RET 2 PLT:

- jump to static address which executes system(), with bash-shell shellcode
- Circumvent DEP
- Fix: PIE

ROP:

- Return Oriented Programming
- Take gadgets from binary
- Gadget are little code sequences, followed with a RET
- Fix: PIE

Canary Brute Force:

- Stack canary is the same on fork (needs execve() for new one)
- 32 Bit canary: 256*4 = 1024 tries to brute force it

Advanced Exploits

Information Disclosure

- The death of anti-exploiting techniques
- Get content past a buffer -> get SIP (Saved Instruction Pointer) or stack pointer
- Relocation happens en-block, so just calculate base address and offset for ret2plt or ROP

Partial Overwrite

- Because of Little-Endianness, can overwrite LSB of function pointers to point to other stuff (not affected by ASLR because in same segment)

Heap attacks

- Use after free
- Double Free
- And lots more