15-213 Recitation
Bomblab (Continued)

Your TAs

Friday, September 13th

Reminders

- **`bomblab`** is due on ***Thursday (Sep 19)***.
- **`attacklab`** will be released on the same day.
- Bootcamp 2: *Debugging & GDB* was pre-recorded, and is available on Piazza (@210).

Agenda

- `bomblab` activity!
- `switch` statements and jump tables

`bomblab` Activity

`bomblab` Activity

- Today, we'll be defusing phases in a *recitation-specific* bomb.
- Format is very similar to real **`bomblab`**
  - But explosions won't notify Autolab, or cost you points!
- Goal is to learn *techniques and concepts* rather than go through **`bomblab`** answers.
  - Don't worry about writing everything down
  - Don't worry if you don't finish all of the phases

`bomblab` Activity

Getting Started

- Download today’s activity handout from the *Schedule* page
- Also download the bomb
- Please use the **Shark Machines** to work on the bomb
- From there, hang tight. We’ll be starting with a demo!

```
$ cp /afs/cs.cmu.edu/academic/class/15213-f24/bomb_reci.tar .
$ tar xvpf bomb_reci.tar
$ gdb bomb
```

Demo: Phase A

Phase B

Phase B: Your Turn

- Now it’s your turn!
- Take a few minutes to try defuse this phase
- Don’t guess!
    - Be methodical: use the techniques we’ve learned
    - Reason about the code before jumping into **`gdb`**
    - This will be useful for the later phases of **`bomblab`**, we promise!

`switch` Statements and Jump Tables

Recall: `switch` statements

```
int main() {
      int x;
      scanf("%d", &x);

      switch (x) {
            case 15205:
                  x += 1;
                  break;
            case 15206:
                  x += 5;
                  /* Fall through */
            case 15207:
                 x += 2;
                  break;
            case 15208:
                  x += 1;
                  break;
            case 15209:
                  x += 3;
                  break;
            case 15213:
                  x += 1;
                  break;
            default:
                  x = 0;
                  break;
            }

      return x;
}
```

Branch on an integer value

Fall through

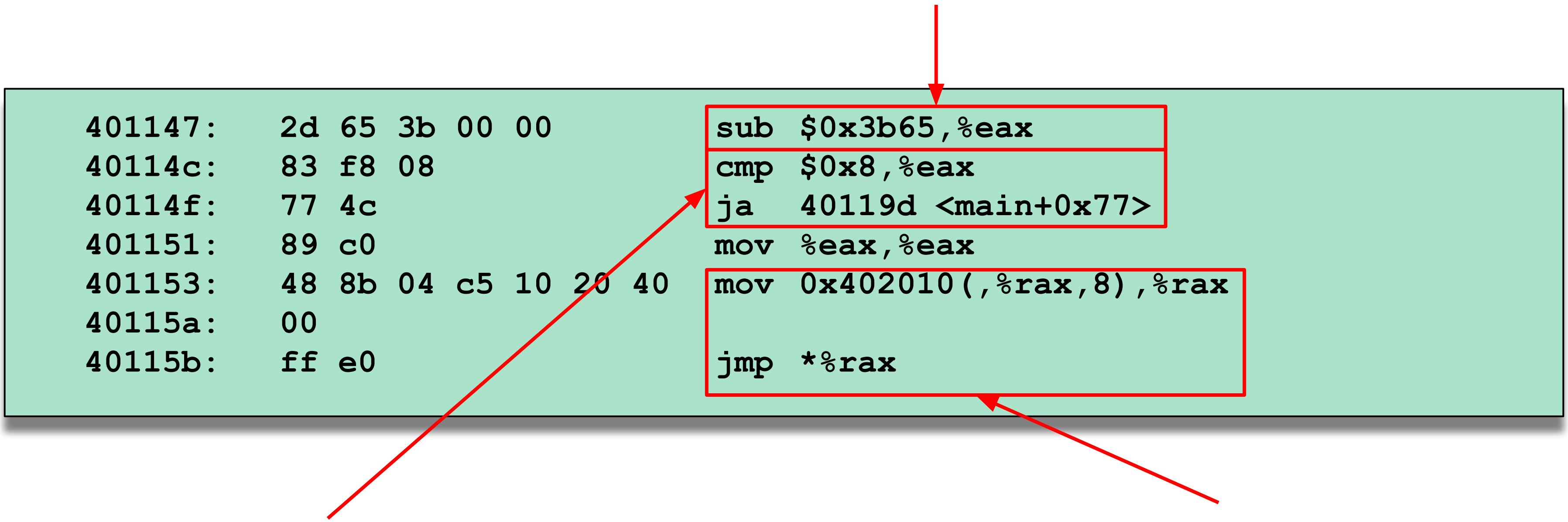
Can have “holes”. No case for 15210!

Recall: Jump Tables

- Compiler decides how to translate **`switch`** based on *heuristics*, for example:
  - Number of cases
  - Sparsity of cases
- Transform the input so we can use it to index into a table of addresses.
- Then just jump to the address at that index.
- ***Idea:*** runtime of **`switch`** becomes independent of the number of cases

Jump Table Assembly: Case 1

Shift range (**15205…15213**) to use zero-based indexing (**0x3b65** = **15205**)

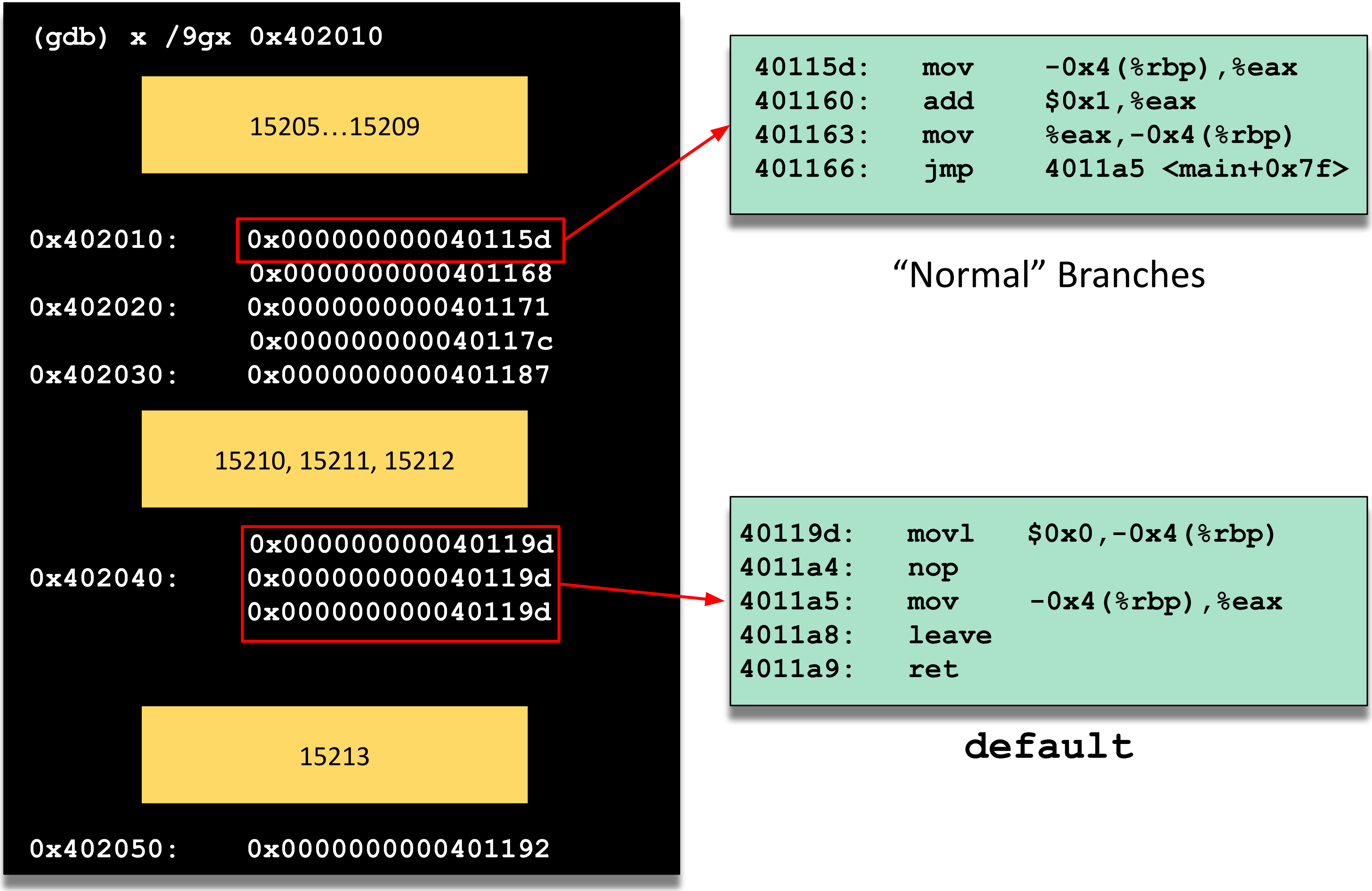


```
401147:    2d 65 3b 00 00          sub  $0x3b65,%eax
40114c:    83 f8 08                cmp  $0x8,%eax
40114f:    77 4c                   ja   40119d <main+0x77>
401151:    89 c0                   mov  %eax,%eax
401153:    48 8b 04 c5 10 20 40    mov  0x402010(,%rax,8),%rax
40115a:    00
40115b:    ff e0                   jmp  *%rax
```

- Jump to default case
- Unsigned comparison is on purpose!

- Grab address from jump table
- Do an indirect jump to that address

Jump Table Assembly: Case 1



```
(gdb) x /9gx 0x402010
```

15205…15209

```
0x402010:     0x000000000040115d
              0x0000000000401168
0x402020:     0x0000000000401171
              0x000000000040117c
0x402030:     0x0000000000401187
```

15210, 15211, 15212

```
              0x000000000040119d
0x402040:     0x000000000040119d
              0x000000000040119d
```

15213

```
0x402050:     0x0000000000401192
```

```
40115d:    mov      -0x4(%rbp),%eax
401160:    add      $0x1,%eax
401163:    mov      %eax,-0x4(%rbp)
401166:    jmp      4011a5 <main+0x7f>
```

“Normal” Branches

```
40119d:    movl     $0x0,-0x4(%rbp)
4011a4:    nop
4011a5:    mov      -0x4(%rbp),%eax
4011a8:    leave
4011a9:    ret
```

`default`

Jump Table Assembly: Case 2

```
401151:   cmp  $0x8,%eax
401154:   ja   4011b8 <main+0x92>
401156:   mov  %eax,%eax
401158:   lea  0x0(,%rax,4),%rdx
40115f:   00
401160:   lea  0xea1(%rip),%rax      # 402008
401167:   mov  (%rdx,%rax,1),%eax
40116a:   cltq
40116c:   lea  0xe95(%rip),%rdx      # 402008
401173:   add  %rdx,%rax
401176:   jmp  *%rax
```

- **rdx = index * 4** (table stores 4 byte offsets)
- **rax** = table base address
- **eax** = offset stored at **table[index]**
- **rdx** = table base address
- Final address = (table base address) + (offset at **table[index]**)

Jump Table Assembly: Case 2

Final Address = *Base Table Address* + `table[index]`

```
(gdb) x /9wx 0x402008
0x402008:     0xffff f170    0xffff f17b    0xffff f184    0xffff f18f
0x402018:     0xffff f19a    0xffff f1b0    0xffff f1b0    0xffff f1b0
0x402028:     0xffff f1a5
(gdb) print /x 0x402008 + 0xffff f170
$1 = 0x401178
```

```
...
401178:    8b 45 fc              mov  -0x4(%rbp),%eax
40117b:    83 c0 01              add  $0x1,%eax
40117e:    89 45 fc              mov  %eax,-0x4(%rbp)
...
```

Yep, that's one of our instructions!

Phase C

Phase C

- Based on what you’ve learned, try to defuse Phase C!