Lecture 9: Buffer Overflows

CS 105

Fall 2020

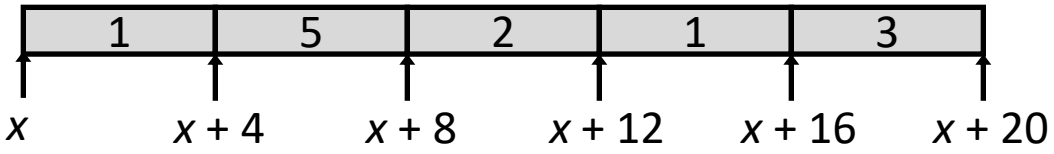
From Last time…

- Basic Principle

  T **A[***L***];**

  - Array of data type *T* and length *L*
  - Identifier **A** can be used as a pointer to array element 0: Type *T**

```
int val[5];
```



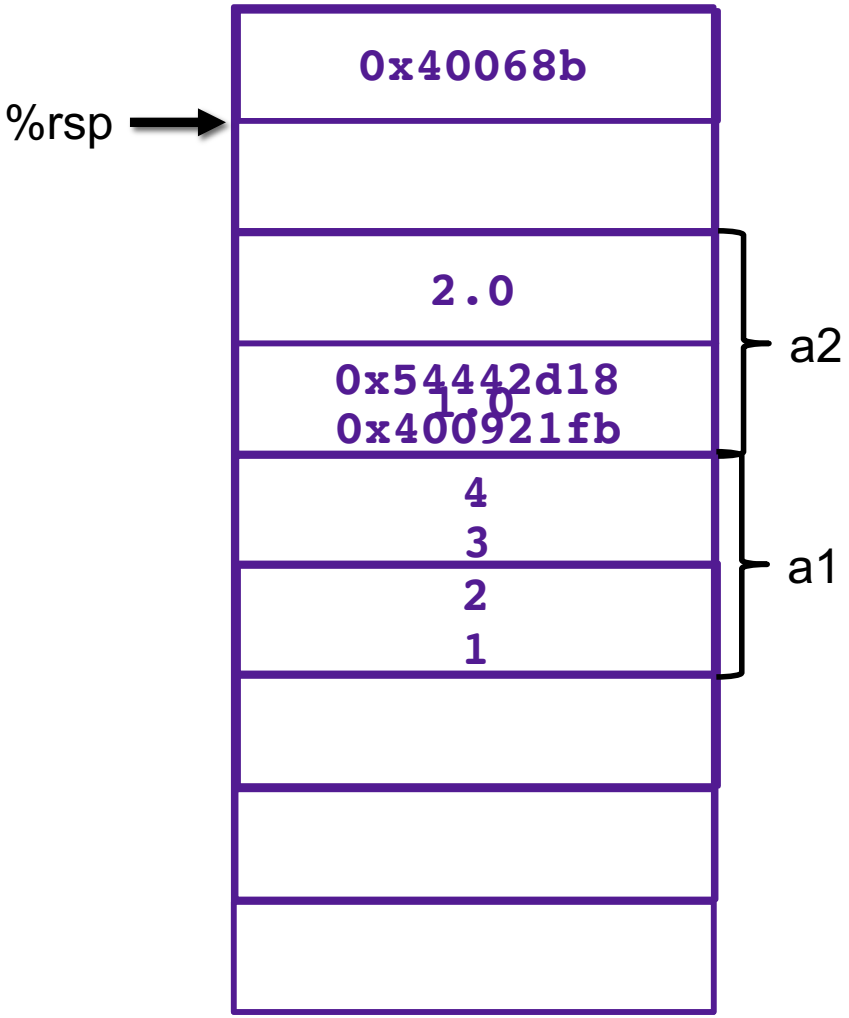
- Reference / Type / Value

Reference	Type	Value
val[4]	**int**	3
val	**int ***	*x*
val+1	**int ***	*x* + 4
&val[2]	**int ***	*x* + 8
val[5]	**int**	??
***(val+1)**	**int**	5
val + *i*	**int ***	*x* + 4 *i*

Memory Referencing Bug Example

```
void f1(){
  double a2[2] = {1.0,2.0};
  int a1[4] = {1,2,3,4};
  a1[4] = 1413754136;
  a1[5] = 1074340347;
```

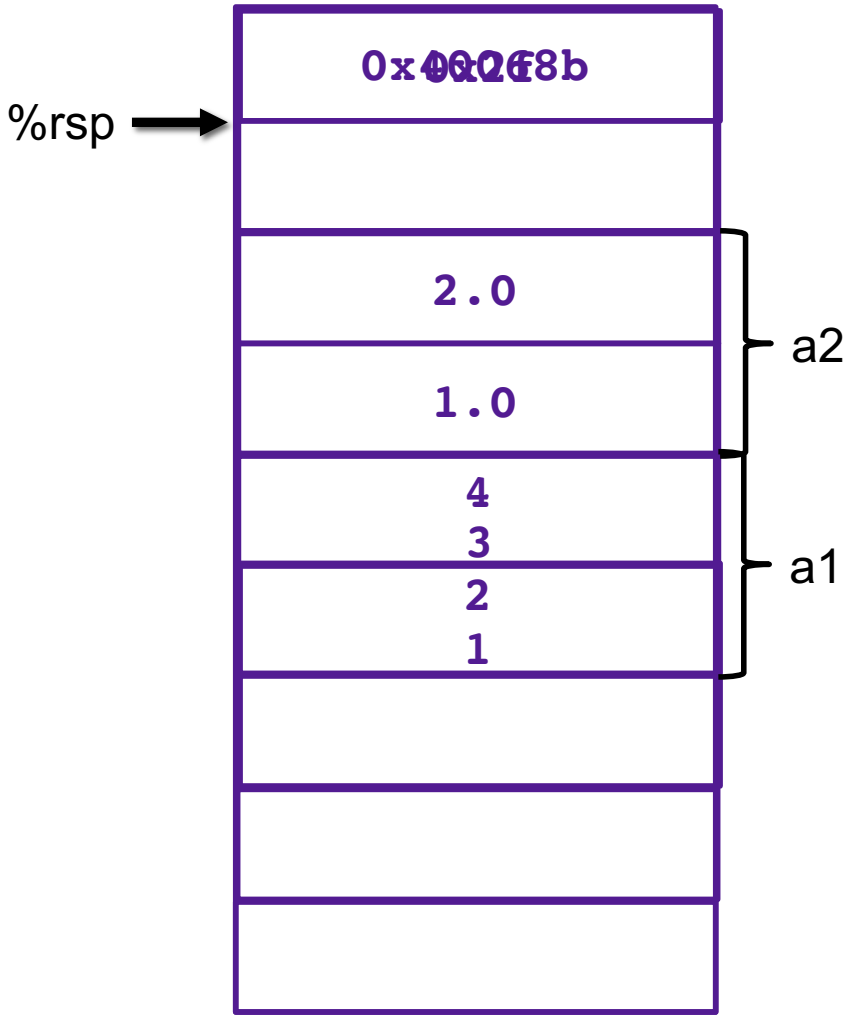
```
f1:
    sub     $0x38,%rsp
    movsd   0x216(%rip),%xmm0
    movsd   %xmm0,0x20(%rsp)
    movsd   0x210(%rip),%xmm0
    movsd   %xmm0,0x28(%rsp)
    movl    $0x1,0x10(%rsp)
    movl    $0x2,0x14(%rsp)
    movl    $0x3,0x18(%rsp)
    movl    $0x4,0x1c(%rsp)
    movl    $0x54442d18,0x20(%rsp)
    movl    $0x400921fb,0x24(%rsp)
    add     $0x38,%rsp
    retq
```



Memory Referencing Bug Example

```
void f1(){
  double a2[2] = {1.0,2.0};
  int a1[4] = {1,2,3,4};
  a1[10] = 47;
}
```

```
f1:
    sub     $0x38,%rsp
    movsd   0x216(%rip),%xmm0
    movsd   %xmm0,0x20(%rsp)
    movsd   0x210(%rip),%xmm0
    movsd   %xmm0,0x28(%rsp)
    movl    $0x1,0x10(%rsp)
    movl    $0x2,0x14(%rsp)
    movl    $0x3,0x18(%rsp)
    movl    $0x4,0x1c(%rsp)
    movl    $0x2f,0x18(%rsp)
    add     $0x38,%rsp
    retq
```

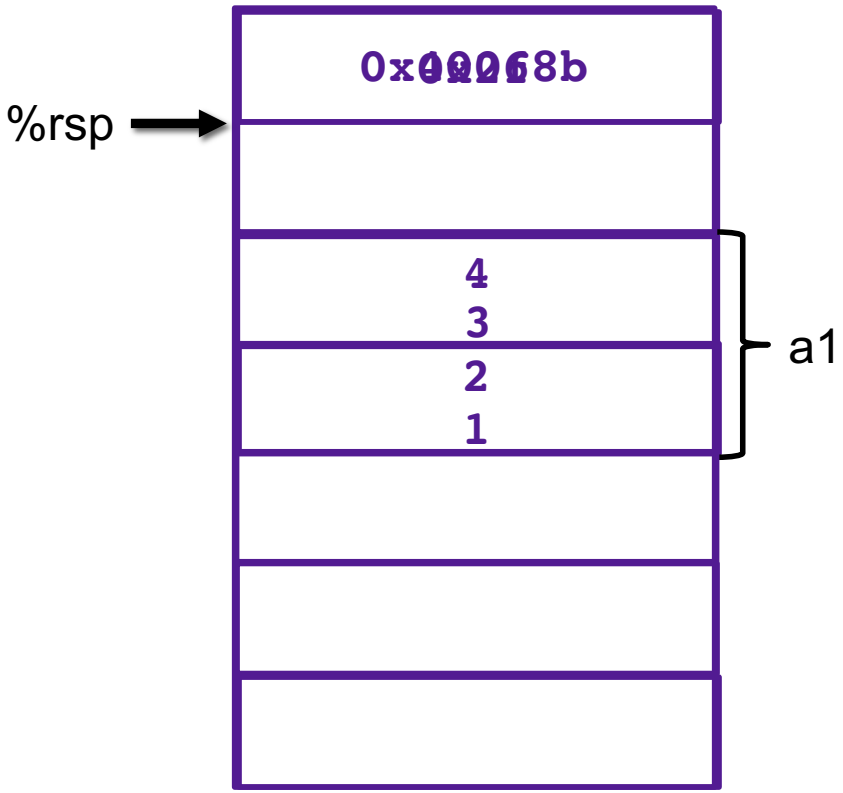


Exercise 1: Memory Bugs

- What is the state of the stack immediately before the program returns from f2?
- What will happen immediately after f2 returns?

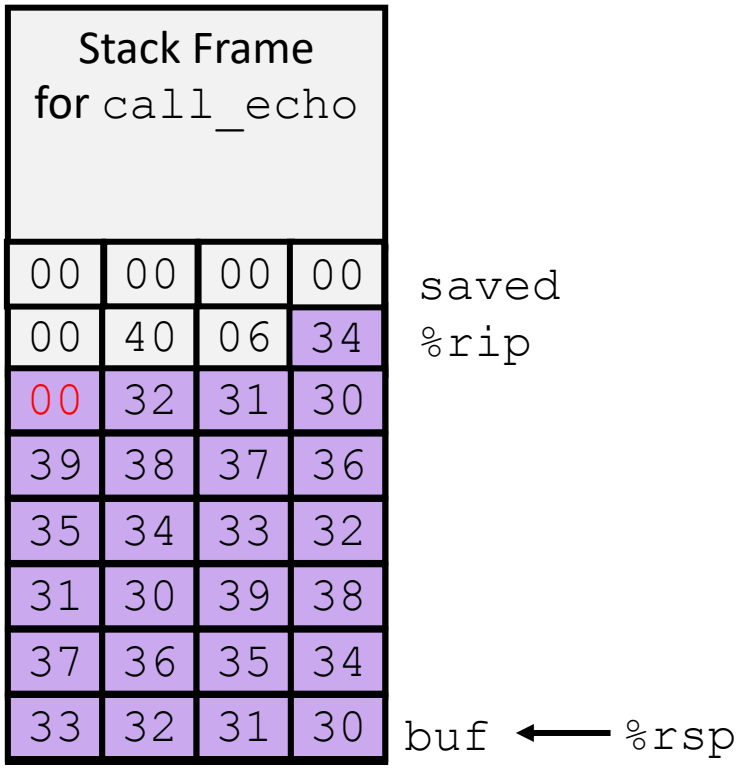
```
int f2(){
  int a1[4] = {1,2,3,4};
  a1[6] = 47;
}
```

```
f2:
   sub     $0x18,%rsp
   movl    $0x1,(%rsp)
   movl    $0x2,0x4(%rsp)
   movl    $0x3,0x8(%rsp)
   movl    $0x4,0xc(%rsp)
   movl    $0x2f,0x18(%rsp)
   add     $0x18,%rsp
   retq
```



Buffer Overflows

- Most common form of memory reference bug
  - Unchecked lengths on string inputs
  - Particularly for bounded character arrays on the stack
    - sometimes referred to as stack smashing




```
/* Echo Line */
void echo()
{
    char buf[4];
    gets(buf);
    puts(buf);
}
```

```
echo:
   subq   $0x18, %rsp
   movq   %rsp, %rdi
   call   gets
   call puts
   addq   $0x18, %rsp
   ret
```

Exercise 2: Buffer O

- Construct an exploit string tha
  program to print "You are now
  the correct password

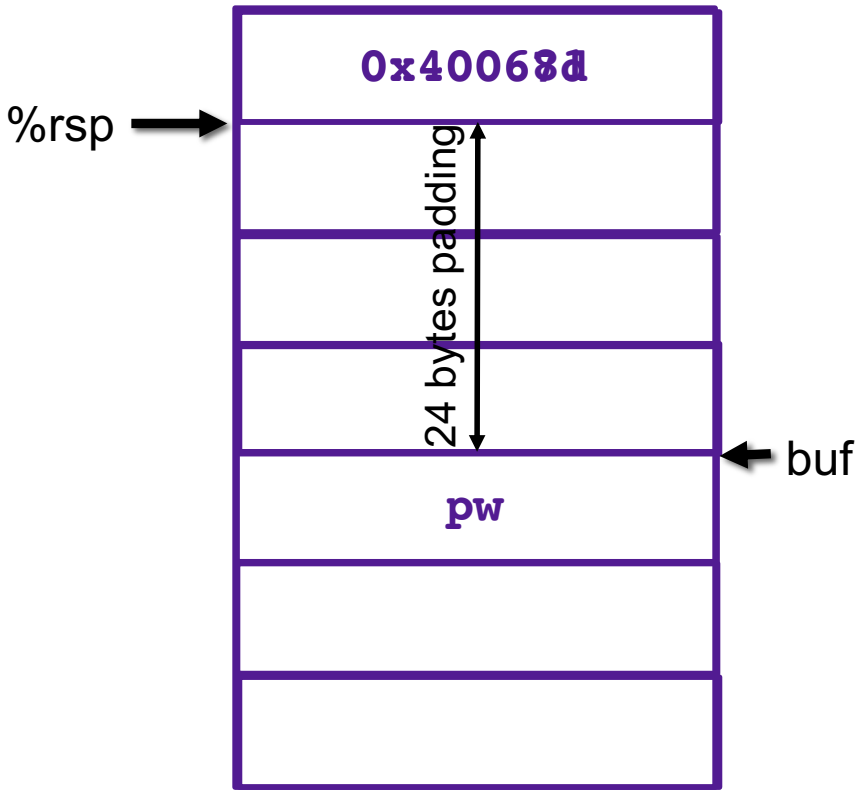
1. How many bytes of padding
2. What value will you overwrit

```
int authenticate(char *password){
  char buf[4];
  gets(buf);
  int correct = !strcmp(password, buf);
  return correct;
}

int main(int argc, char ** argv){
  char * pw = "123456";
  printf("Enter your password: ");
  while(!authenticate(pw)){
    printf("Incorrect. Try again: ");
  }
  printf("You are now logged in\n");
  return 0;
}
```

```
authenticate:
   0x4005f6 <+0>:  sub    $0x28,%rsp
   0x4005fa <+4>:  mov    %rdi,0x8(%rsp)
   0x4005ff <+9>:  lea    0x10(%rsp),%rax
   0x400604 <+14>: mov    %rax,%rdi
   0x400607 <+17>: mov    $0x0,%eax
   0x40060c <+22>: callq  0x4004e0 <gets@plt>
   0x400611 <+27>: lea    0x10(%rsp),%rdx
   0x400616 <+32>: mov    0x8(%rsp),%rax
   0x40061b <+37>: mov    %rdx,%rsi
   0x40061e <+40>: mov    %rax,%rdi
   0x400621 <+43>: callq  0x4004d0 <strcmp@plt>
   0x400626 <+48>: test   %eax,%eax
   0x400628 <+50>: sete   %al
   0x40062b <+53>: movzbl %al,%eax
   0x400636 <+64>: add    $0x28,%rsp
   0x40063a <+68>: retq
main:
   0x40063b <+0>:  sub    $0x28,%rsp
   0x40063f <+4>:  mov    %edi,0xc(%rsp)
   0x400643 <+8>:  mov    %rsi,(%rsp)
   0x400647 <+12>: movq   $0x400728,0x18(%rsp)
   0x400650 <+21>: mov    $0x40072f,%edi
   0x400655 <+26>: mov    $0x0,%eax
   0x40065a <+31>: callq  0x4004b0 <printf@plt>
   0x40065f <+36>: jmp    0x400670 <main+53>
   0x400661 <+38>: mov    $0x400748,%edi
   0x400666 <+43>: mov    $0x0,%eax
   0x40066b <+48>: callq  0x4004b0 <printf@plt>
   0x400670 <+53>: mov    0x18(%rsp),%rax
   0x400675 <+58>: mov    %rax,%rdi
   0x400678 <+61>: callq  0x4005f6 <authenticate>
   0x40067d <+66>: test   %eax,%eax
   0x40067f <+68>: je     0x400661 <main+38>
   0x400681 <+70>: mov    $0x400768,%edi
   0x400686 <+75>: callq  0x4004a0 <puts@plt>
   0x040068b <+80>: mov    $0x0,%eax
   0x400690 <+85>: add    $0x28,%rsp
   0x400694 <+89>: retq
```

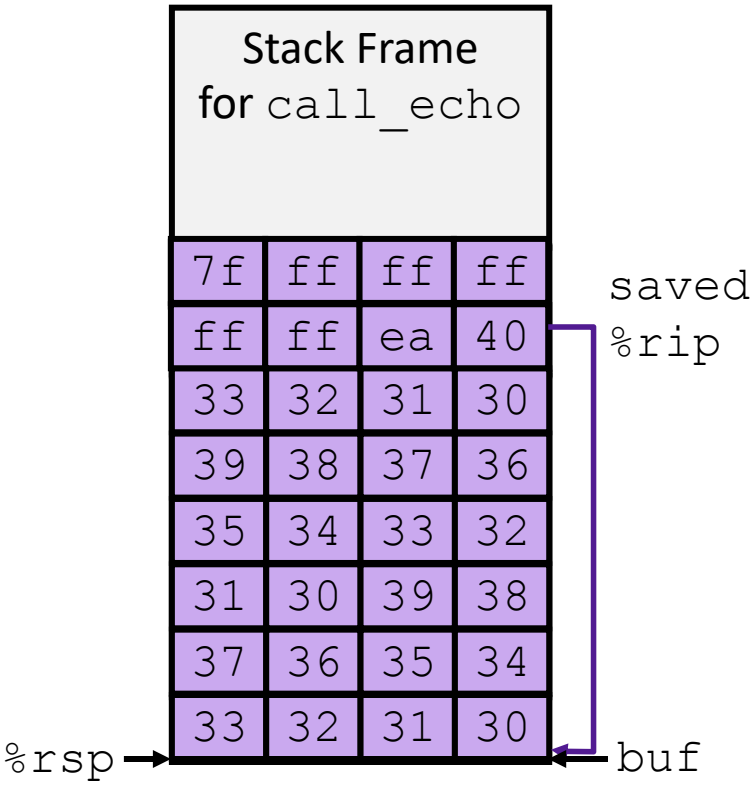
Exercise 2: Buffer O




```
authenticate:
   0x4005f6 <+0>:  sub    $0x28,%rsp
   0x4005fa <+4>:  mov    %rdi,0x8(%rsp)
   0x4005ff <+9>:  lea    0x10(%rsp),%rax
   0x400604 <+14>: mov    %rax,%rdi
   0x400607 <+17>: mov    $0x0,%eax
   0x40060c <+22>: callq  0x4004e0 <gets@plt>
   0x400611 <+27>: lea    0x10(%rsp),%rdx
   0x400616 <+32>: mov    0x8(%rsp),%rax
   0x40061b <+37>: mov    %rdx,%rsi
   0x40061e <+40>: mov    %rax,%rdi
   0x400621 <+43>: callq  0x4004d0 <strcmp@plt>
   0x400626 <+48>: test   %eax,%eax
   0x400628 <+50>: sete   %al
   0x40062b <+53>: movzbl %al,%eax
   0x400636 <+64>: add    $0x28,%rsp
   0x40063a <+68>: retq
main:
   0x40063b <+0>:  sub    $0x28,%rsp
   0x40063f <+4>:  mov    %edi,0xc(%rsp)
   0x400643 <+8>:  mov    %rsi,(%rsp)
   0x400647 <+12>: movq   $0x400728,0x18(%rsp)
   0x400650 <+21>: mov    $0x40072f,%edi
   0x400655 <+26>: mov    $0x0,%eax
   0x40065a <+31>: callq  0x4004b0 <printf@plt>
   0x40065f <+36>: jmp    0x400670 <main+53>
   0x400661 <+38>: mov    $0x400748,%edi
   0x400666 <+43>: mov    $0x0,%eax
   0x40066b <+48>: callq  0x4004b0 <printf@plt>
   0x400670 <+53>: mov    0x18(%rsp),%rax
   0x400675 <+58>: mov    %rax,%rdi
   0x400678 <+61>: callq  0x4005f6 <authenticate>
   0x40067d <+66>: test   %eax,%eax
   0x40067f <+68>: je     0x400661 <main+38>
   0x400681 <+70>: mov    $0x400768,%edi
   0x400686 <+75>: callq  0x4004a0 <puts@plt>
   0x040068b <+80>: mov    $0x0,%eax
   0x400690 <+85>: add    $0x28,%rsp
   0x400694 <+89>: retq
```

Stack Smashing

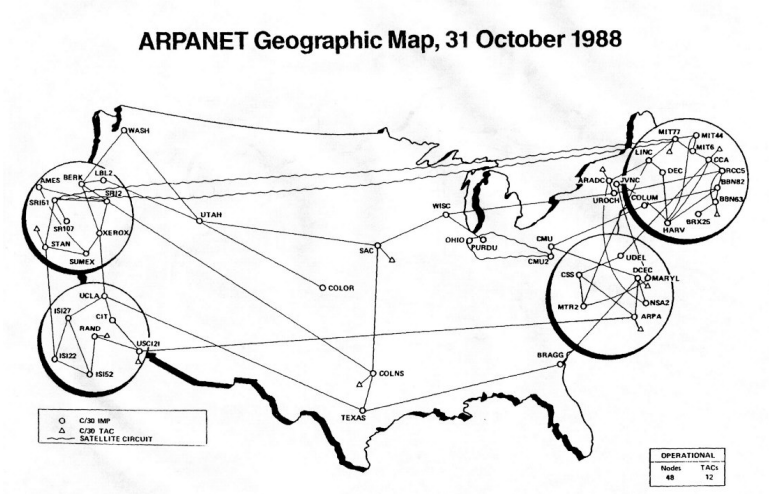
- Idea: fill the buffer with bytes that will be interpreted as code
- Overwrite the return address with address of the beginning of the buffer




```
/* Echo Line */
void echo()
{
    char buf[4];
    gets(buf);
    puts(buf);
}
```

```
echo:
  subq  $18, %rsp
  movq  %rsp, %rdi
  call  gets
  call puts
  addq  $18, %rsp
  ret
```

Buffer Overflow Examples



Exercise 4: Feedback

1. Rate how well you think this recorded lecture worked
    1. Better than an in-person class
    2. About as well as an in-person class
    3. Less well than an in-person class, but you still learned something
    4. Total waste of time, you didn't learn anything
2. How much time did you spend on this video lecture (including time spent on exercises)?
3. Do you have any questions that you would like me to address in this week's problem session?
4. Do you have any other comments or feedback?