

Buffer Overflow



String Library Code

```
/* Get string input, store to str */
char* gets(char* str) {
    int c = getchar();
    char* p = str;
    while (c != '\n' && c != EOF) {
        *p++ = c;
        c = getchar();
    }
    *p = '\0';
    return str;
}
```

↑
end-of-file
(input) marker

```
char* strcpy(char* dest, char* src); // copy string
// see also: strcat, scanf, fscanf, sscanf, ...
```

```
char* fgets(char* str, int n, FILE* stream);
char* strncpy(char* dest, char* src, size_t n);
```

Vulnerable Buffer Code

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

```
void call_echo() {
    echo();
}
```

```
unix> ./buftest
Type a string: 012345678901234567890123
012345678901234567890123
```

```
unix> ./buftest
Type a string: 0123456789012345678901234
Segmentation Fault
```

Buffer Overflow Assembly

echo:

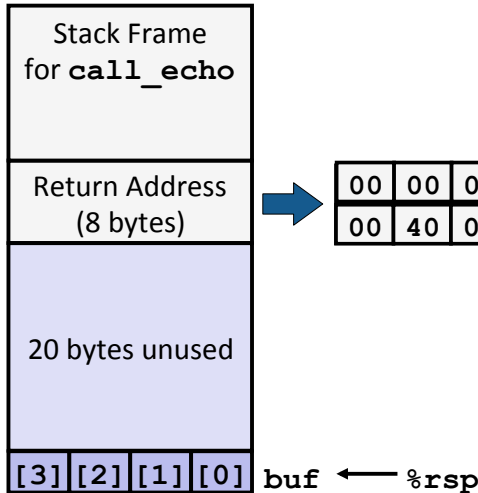
00000000004006cf <echo>:	
4006cf: 48 83 ec 18	sub \$0x18,%rsp
4006d3: 48 89 e7	mov %rsp,%rdi
4006d6: e8 a5 ff ff ff	callq 400680 <gets>
4006db: 48 89 e7	mov %rsp,%rdi
4006de: e8 3d fe ff ff	callq 400520 <puts@plt>
4006e3: 48 83 c4 18	add \$0x18,%rsp
4006e7: c3	retq

call_echo:

4006e8: 48 83 ec 08	sub \$0x8,%rsp
4006ec: b8 00 00 00 00	mov \$0x0,%eax
4006f1: e8 d9 ff ff ff	callq 4006cf <echo>
4006f6: 48 83 c4 08	add \$0x8,%rsp
4006fa: c3	retq

Buffer Overflow Stack

Before call to gets



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

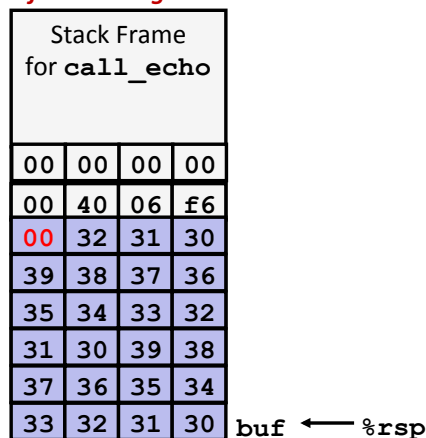
```
echo:
    subq $24, %rsp
    movq %rsp, %rdi
    call gets
    . . .
```

call_echo:

```
. . .
4006f1: callq 4006cf <echo>
4006f6: add $0x8,%rsp
. . .
```

Buffer Overflow Examples

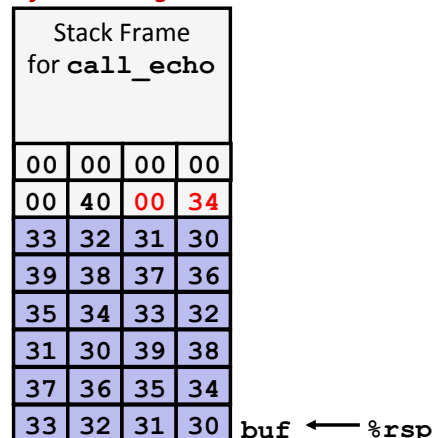
After call to gets



```
unix> ./buftest
Type a string: 01234567890123456789012
01234567890123456789012
```

Overflowed, but did not corrupt state

After call to gets



```
unix> ./buftest
Type a string: 0123456789012345678901234
Segmentation Fault
```

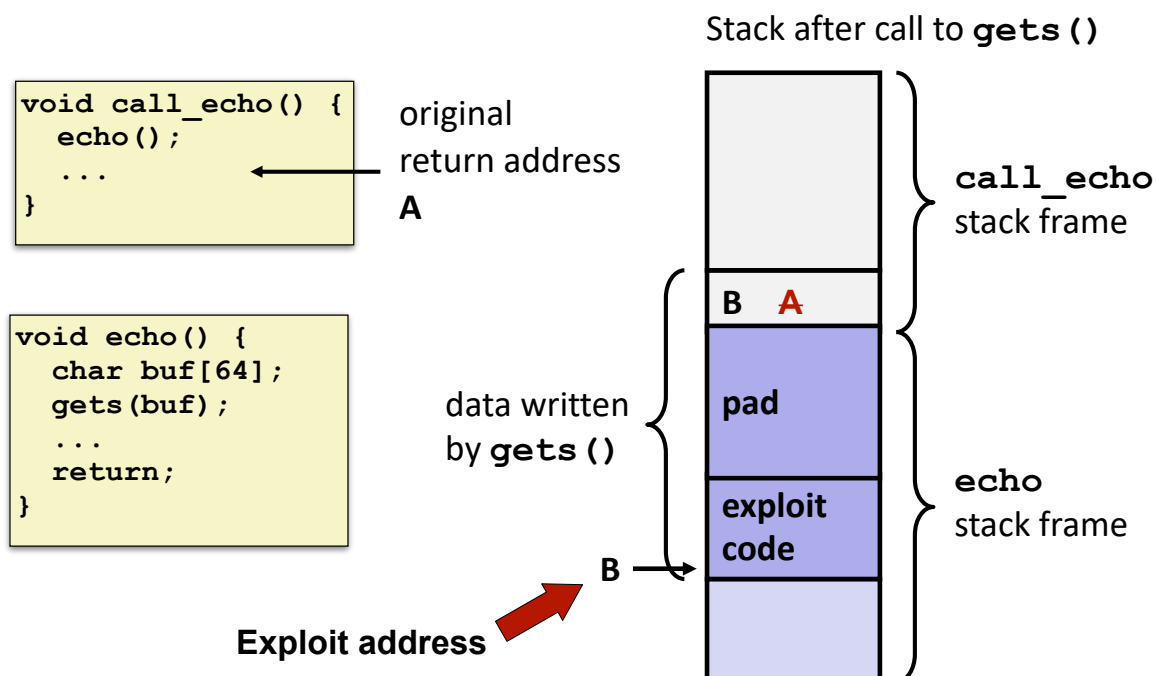
Overflowed and corrupted return pointer

Character Representations (redux)

ASCII Table

Dec	Hex	Oct	Char	Dec	Hex	Oct	Char	Dec	Hex	Oct	Char	Dec	Hex	Oct	Char
0	0	0		32	20	40	[space]	64	40	100	@	96	60	140	`
1	1	1		33	21	41	!	65	41	101	A	97	61	141	a
2	2	2		34	22	42	"	66	42	102	B	98	62	142	b
3	3	3		35	23	43	#	67	43	103	C	99	63	143	c
4	4	4		36	24	44	\$	68	44	104	D	100	64	144	d
5	5	5		37	25	45	%	69	45	105	E	101	65	145	e
6	6	6		38	26	46	&	70	46	106	F	102	66	146	f
7	7	7		39	27	47	'	71	47	107	G	103	67	147	g
8	8	10		40	28	50	(	72	48	110	H	104	68	150	h
9	9	11		41	29	51	)	73	49	111	I	105	69	151	i
10	A	12		42	2A	52	*	74	4A	112	J	106	6A	152	j
11	B	13		43	2B	53	+	75	4B	113	K	107	6B	153	k
12	C	14		44	2C	54	,	76	4C	114	L	108	6C	154	l
13	D	15		45	2D	55	-	77	4D	115	M	109	6D	155	m
14	E	16		46	2E	56	.	78	4E	116	N	110	6E	156	n
15	F	17		47	2F	57	/	79	4F	117	O	111	6F	157	o
16	10	20		48	30	60	0	80	50	120	P	112	70	160	p
17	11	21		49	31	61	1	81	51	121	Q	113	71	161	q
18	12	22		50	32	62	2	82	52	122	R	114	72	162	r
19	13	23		51	33	63	3	83	53	123	S	115	73	163	s
20	14	24		52	34	64	4	84	54	124	T	116	74	164	t
21	15	25		53	35	65	5	85	55	125	U	117	75	165	u
22	16	26		54	36	66	6	86	56	126	V	118	76	166	v
23	17	27		55	37	67	7	87	57	127	W	119	77	167	w
24	18	30		56	38	70	8	88	58	130	X	120	78	170	x
25	19	31		57	39	71	9	89	59	131	Y	121	79	171	y
26	1A	32		58	3A	72	:	90	5A	132	Z	122	7A	172	z
27	1B	33		59	3B	73	;	91	5B	133	[	123	7B	173	{
28	1C	34		60	3C	74	<	92	5C	134	\	124	7C	174	
29	1D	35		61	3D	75	=	93	5D	135	]	125	7D	175	}
30	1E	36		62	3E	76	>	94	5E	136	^	126	7E	176	~
31	1F	37		63	3F	77	?	95	5F	137	_	127	7F	177	

Code Injection Attacks



Best Practices

Use length-limited string routines (**fgets**, **strncpy**, ...)

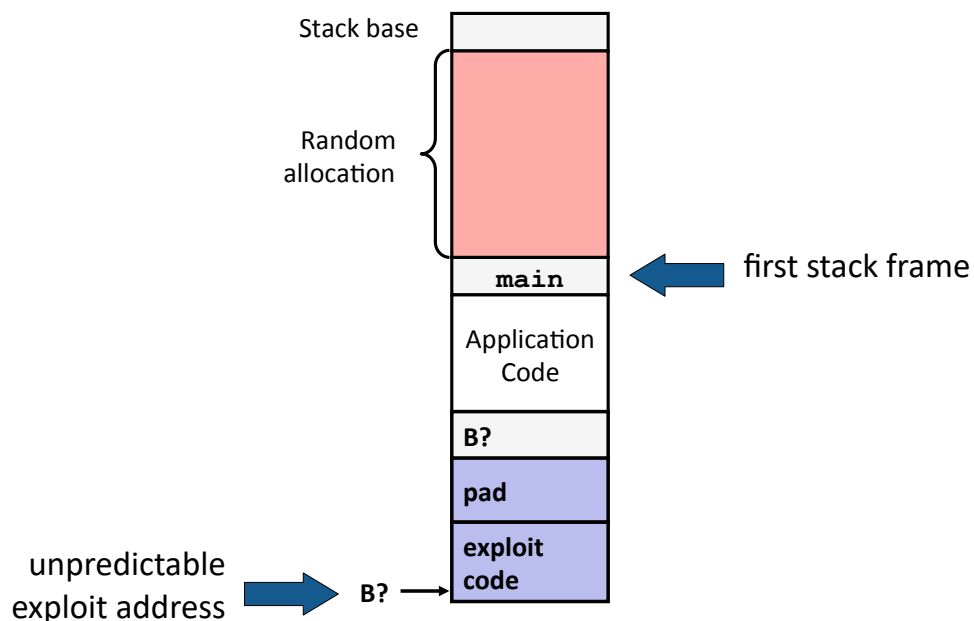
No **%s** in **scanf**

... etc ...

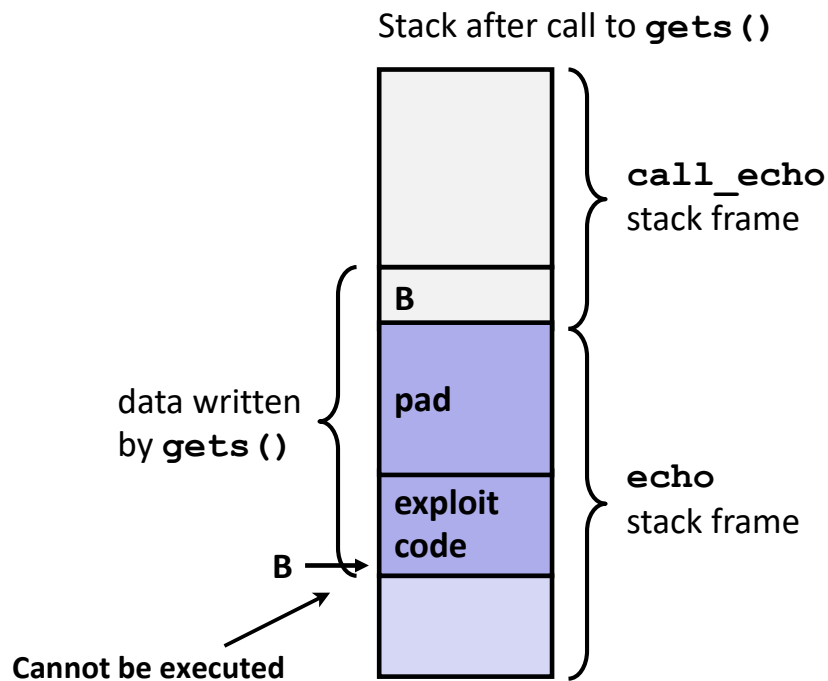
Don't make any mistakes...

```
/* Echo Line */  
void echo() {  
    char buf[64];  
    fgets(buf, 64, stdin); // safe  
    puts(buf);  
}
```

Address Space Layout Randomization (ASLR)



Non-Executable Memory Segments

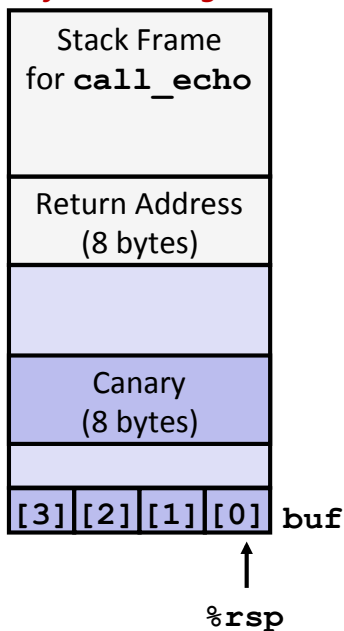


Stack Canaries



Stack Canary Example

Before call to gets

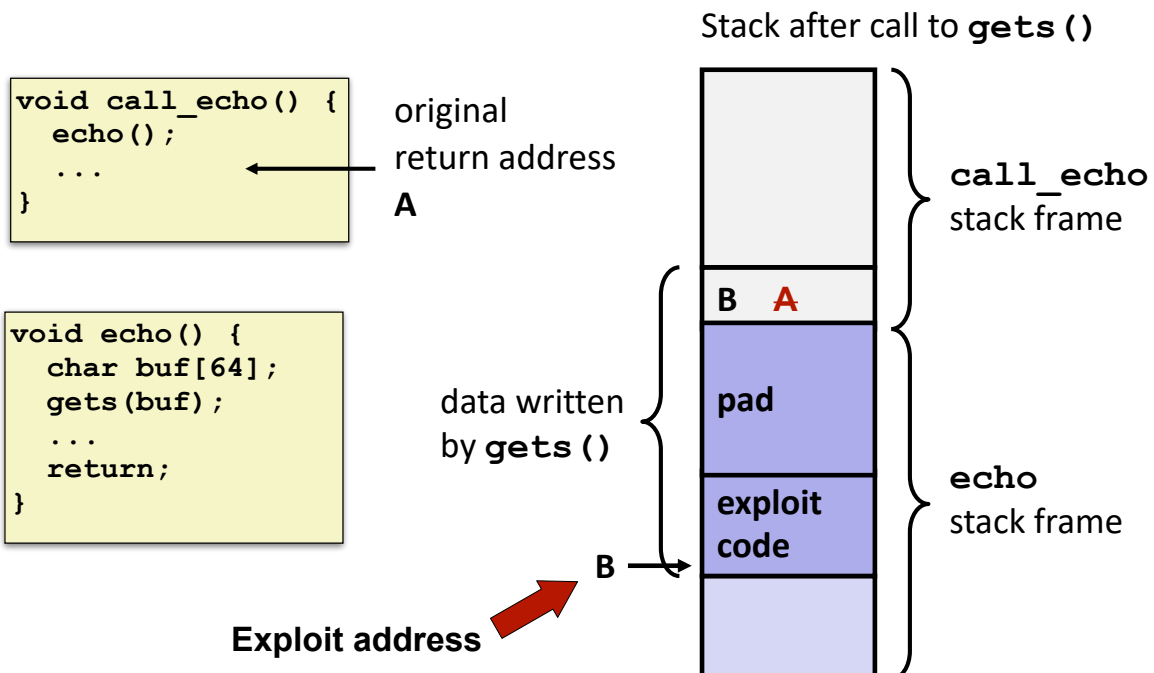


```
/* Echo Line */
void echo() {
    char buf[4]; /* Way too small! */
    gets(buf);
    puts(buf);
}
```

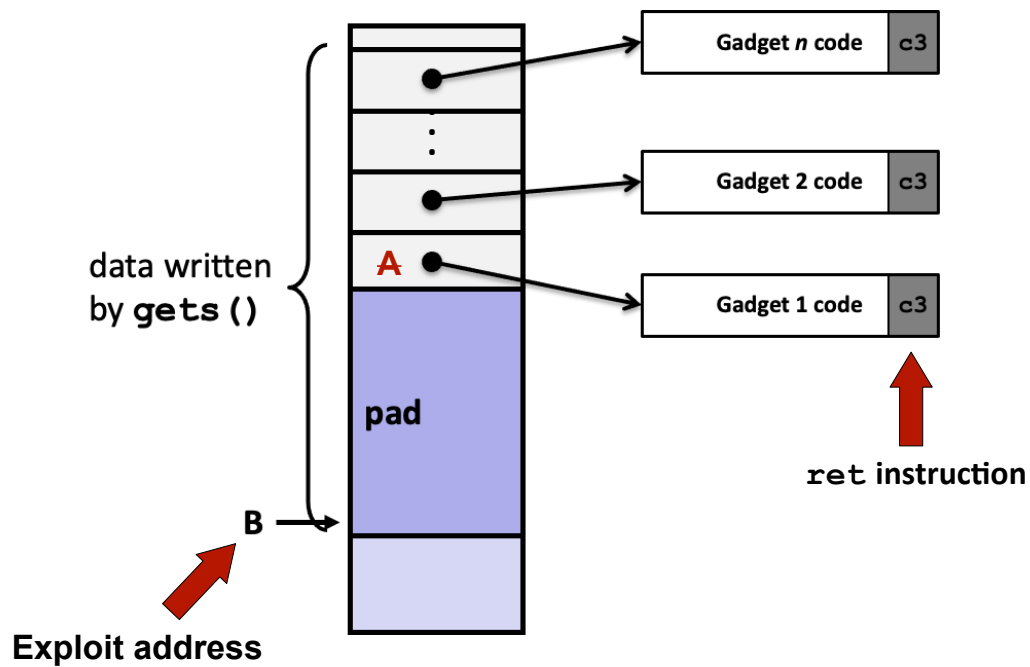
echo:

```
40072f: sub    $0x18,%rsp
400733: mov    %fs:0x28,%rax # Get canary
40073c: mov    %rax,0x8(%rsp) # Put on stack
400741: xor    %eax,%eax
400743: mov    %rsp,%rdi
400746: callq  4006e0 <gets>
40074b: mov    %rsp,%rdi
40074e: callq  400570 <puts@plt>
400753: mov    0x8(%rsp),%rax # Retrieve canary
400758: xor    %fs:0x28,%rax # Check canary
400761: je     400768 <echo+0x39>
400763: callq  400580 <__stack_chk_fail@plt>
400768: add    $0x18,%rsp
40076c: retq
```

Code Injection Attacks (redux)



Return-Oriented Programming (ROP)



Partial Functions as Gadgets

```
long ab_plus_c(long a, long b, long c) {  
    return a * b + c;  
}
```

```
00000000004004d0 <ab_plus_c>:  
4004d0: 48 0f af fe  imul %rsi,%rdi  
4004d4: 48 8d 04 17  lea (%rdi,%rdx,1),%rax  
4004d8: c3           retq
```

$\text{rax} \leftarrow \text{rdi} + \text{rdx}$

Gadget address = 0x4004d4

Partial Instructions as Gadgets

```
void setval(unsigned *p) {  
    *p = 3347663060u;  
}
```

