Defending Computer Networks
Lecture 2: Vulnerabilities

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Evaluation Correction

- 30% in-class quizzes (3).
  - Dates TBD.
- 30% homework assignments.
  - Mostly practical lab-based exercises using common network security tools, or short coding tasks to illustrate principles.
- 40% class project.
  - non-trivial piece of C code from scratch to do an interesting task in network security.
    - Architecture document (10% of total grade)
    - **Demonstrate code working at an interim milestone (10%)**
    - Demonstrate code towards the end of the course (20%).
    - Project will likely be done in small groups.
    - Details will be released a couple of weeks into the course.
- No final.

Other Logistics

- Not much happened over holiday
- T.A. is still TBD
  - Good news is still no homework ☺
- Class still not official
  - Class sign-up roster going around
    - Name -- Net-ID -- Program/Field
    - Will go to Stephanie Meik
    - She will resolve enrollment uncertainty

Main Goals for Today

- Understand system() function vulnerabilities
- Outline understanding of buffer overflow vulnerabilities

Interesting News This Week

Marine Website Compromised With Pro-Assad Message

By THE ASSOCIATED PRESS
Published: September 2, 2013 at 1:59 PM ET

WASHINGTON — A Marine Corps spokesman says the Marines' recruiting website was tampered with and redirected temporarily, but no information was put at risk.

Capt. Eric Flanagan wouldn't say who was responsible for the hacking, but the site was redirected to a message from the Syrian Electronic Army, a hacker group that's claimed responsibility for disrupting the New York Times website, Twitter and other media sites the group sees as sympathetic to Syria's rebels.

More Interesting News

The Washington Post | PostTV | Politi

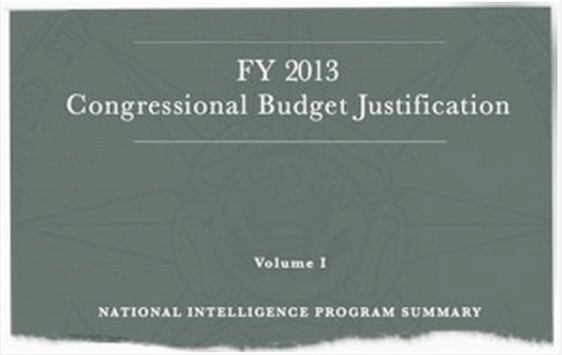
National Securi

By Barton Gellman and Ellen Nakashima, Published: August 30 E-mail the writers

U.S. intelligence services carried out 231 offensive cyber-operations in 2011, the leading edge of a clandestine campaign that embraces the Internet as a theater of spying, sabotage and war, according to top-secret documents obtained by The Washington Post.

That disclosure, in a classified intelligence budget provided by NSA leaker Edward Snowden, provides new evidence that the Obama administration's growing ranks of cyberwarriors infiltrate and disrupt foreign computer networks.

Read the documents



Inside the secret 'black budget'

View select pages from the Office of the Director of National Intelligence's top-secret 2013 budget with key sections annotated by The Washington Post.

Related:

'Black budget' reveals a U.S. intelligence-gathering giant

Barton Gellman and Greg Miller AUG 29
Despite huge funding, agencies are

Additionally, under an extensive effort code-named GENIE, U.S. computer specialists break into foreign networks so that they can be put under surreptitious U.S. control. Budget documents say the $652 million project has placed "covert implants," sophisticated malware transmitted from far away, in computers, routers and firewalls on tens of thousands of machines every year, with plans to expand those numbers into the millions.

The documents provided by Snowden and interviews with former U.S. officials describe a campaign of computer intrusions that is far broader and more aggressive than previously understood. The Obama administration treats all such cyber-operations as clandestine and declines to acknowledge them.

System() Function Vulnerabilities

- Very basic class of C/Unix vulnerability
- “man 3 system”
- Been known for decades
- Still occurs, however.
- Let’s work through an example

```
#include <stdio.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <assert.h>
#include <strings.h>
#include <unistd.h>
#include <stdlib.h>

// This code is a very short hack to illustrate server vulnerabilities!!
// Do not write production code like this!!!
int               sockFd;
int               connFd;
unsigned short    port          = 3333;
struct sockaddr_in  serverAddress;
struct sockaddr_in  clientAddress;
```

```
void setupSocket(void)
{
  unsigned clientLen;
  assert( (sockFd = socket(AF_INET, SOCK_STREAM, 0)) >= 0);
  bzero(&serverAddress, sizeof(struct sockaddr_in));
  serverAddress.sin_family      = AF_INET;
  serverAddress.sin_addr.s_addr = INADDR_ANY;
  serverAddress.sin_port        = htons(port);
  assert(bind(sockFd, (struct sockaddr *) &serverAddress, sizeof(struct sockaddr_in)) >= 0);
  assert(listen(sockFd, 5)>=0);
  clientLen = sizeof(struct sockaddr_in);
  assert( (connFd = accept(sockFd, (struct sockaddr *)&clientAddress, &clientLen)) > 1);
}
```

```
int getLineFromSocket(char* buffer, int len)
{
  int n;
  assert(write(connFd, "Type Symbol>", 12) >= 0);
  n = read(connFd, buffer, len);
  buffer[n-2] = '\0';
  return n;
}
```

```
void extractCountFromFile(char* fileName, char* answer)
{
  char buf[256];
  char* start;

  FILE* file = fopen(fileName, "r");
  assert(file);
  fgets(buf, 256, file);
  for(start = buf; *start; start++)
  {
    if(*start == ' ' || *start == '\t')
      continue;
    else
      break;
  }
  if(*start)
  {
    char* end = index(start, ' ');
    if(end)
    {
      *end = '\n';
      *(++end) = '\0';
      strcpy(answer, start);
    }
  }
}
```

```
void processLine(char* buffer, int len)
{
  // line format is "username\n"
  char answer[256];
  char command[256];
  sprintf(command, "ps aux |grep %s |wc > tmp.txt", buffer);
  fprintf(stdout, "Buf %s\n", buffer);
  fprintf(stdout, "About to execute %s\n", command);
  system(command);
  extractCountFromFile("tmp.txt", answer);
  assert(write(connFd, answer, strlen(answer)) >= 0);
}
```

```
int main(int argc, char* argv[])
{
  char buf[256];
  int n;
  if(argc ==2)
  {
   port = atoi(argv[1]);
  }
  setupSocket();
  while(getLineFromSocket(buf, 256))
    processLine(buf, n);
}
```

Live Demonstration of Exploitation

General Point

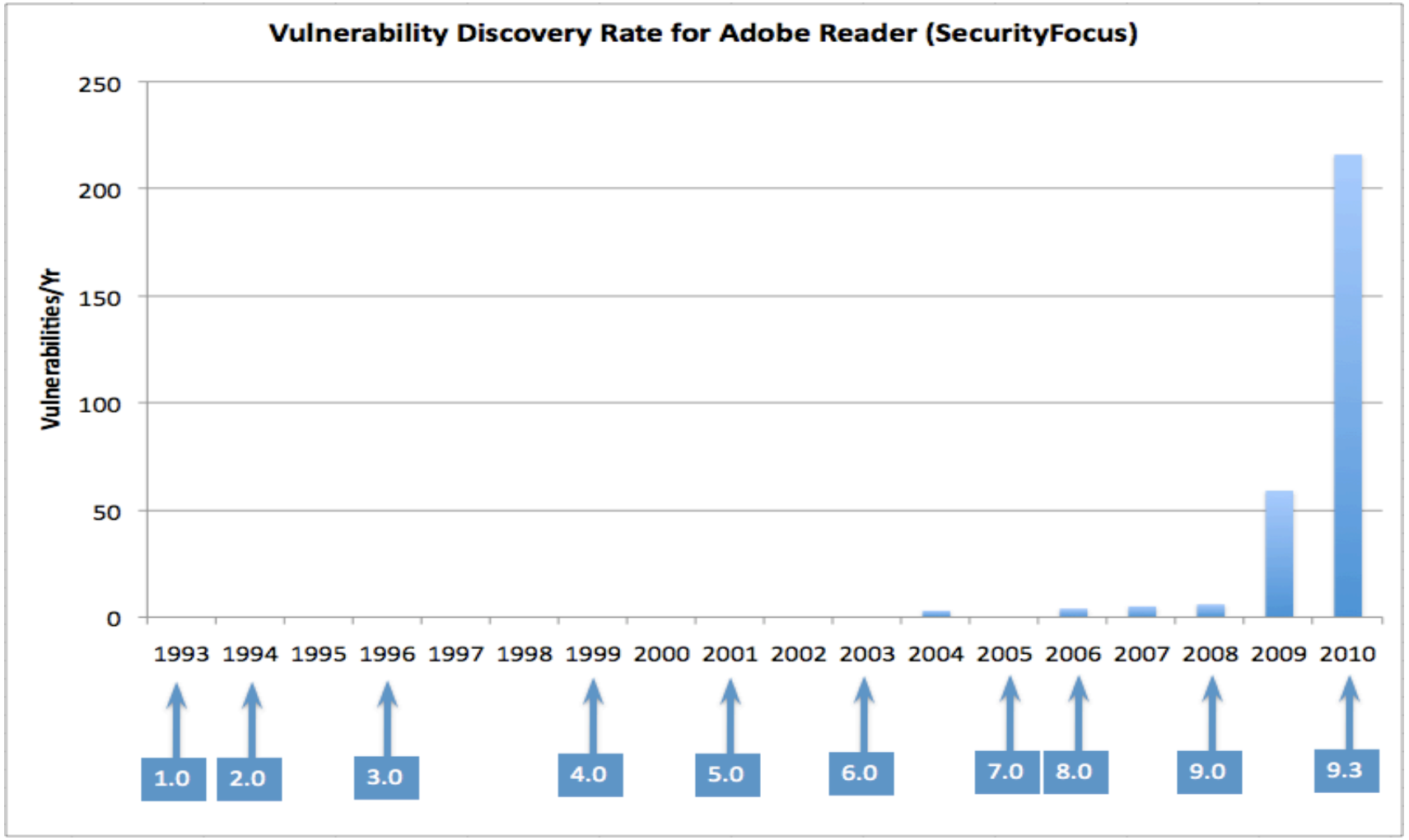
- When writing a server
  - Task is to mediate access to server's resources
  - Not grant arbitrary access
  - Have to be very careful in channeling
    - Constrained client-server protocol
    - To general-purpose OS/computer
- Attackers are evil/bad/smart/patient
- They are out to get you!


I must not tell lies

Side Note

- SQL Injection Vulnerabilities are closely related
  - Eg ';' passed through to SQL server is a statement separator there too.
- The general issue is failure to properly sanitize input before passing it to general execution engines.

Interlude


Vulnerability Discovery Rate for Adobe Reader (SecurityFocus)
Vulnerabilities/Yr
250
200
150
100
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0
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
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9.3

Buffer Overflow Vulnerabilities

- Most important early class of vulnerabilities
  - Still important
- Will start today, finish in subsequent lecture(s)
- Today, will introduce a "fictionalized" account
  - How things used to be 10-20 years ago
  - Simpler to understand
  - Will not match what happens if you look at output of a modern compiler
    - Modern OS/compilers have numerous defenses
    - Still vulnerable though, just more complex to exploit
  - We will expand into more realistic detail next time
- Loosely based on Aleph1 *Smashing Stack for Fun and Profit*.
  - http://www-inst.eecs.berkeley.edu/~cs161/fa08/papers/stack_smashing.pdf

Example 1

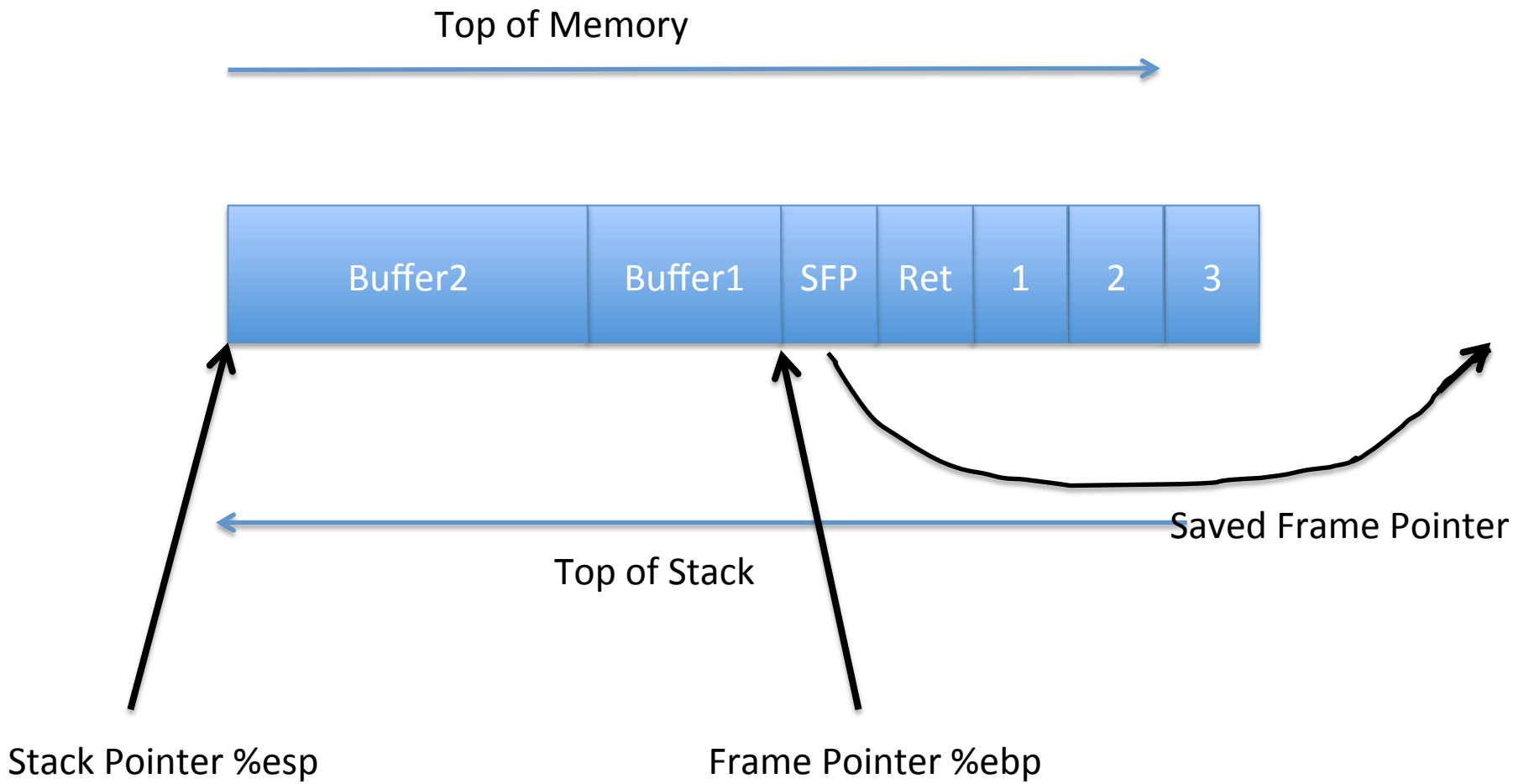
```
void myFunc(int a, int b, int c)
{
  char buffer1[5];
  char buffer2[10];
}

int main(int argc, char* argv[])
{
  myFunc(1,2,3);
}
```

Assembler

- Function Call:
  - pushl $3
  - pushl $2
  - pushl $1
  - call myFunc
- Function Prologue:
  - pushl %ebp
  - movl %esp,%ebp
  - subl $20,%esp

Stack in Example 1

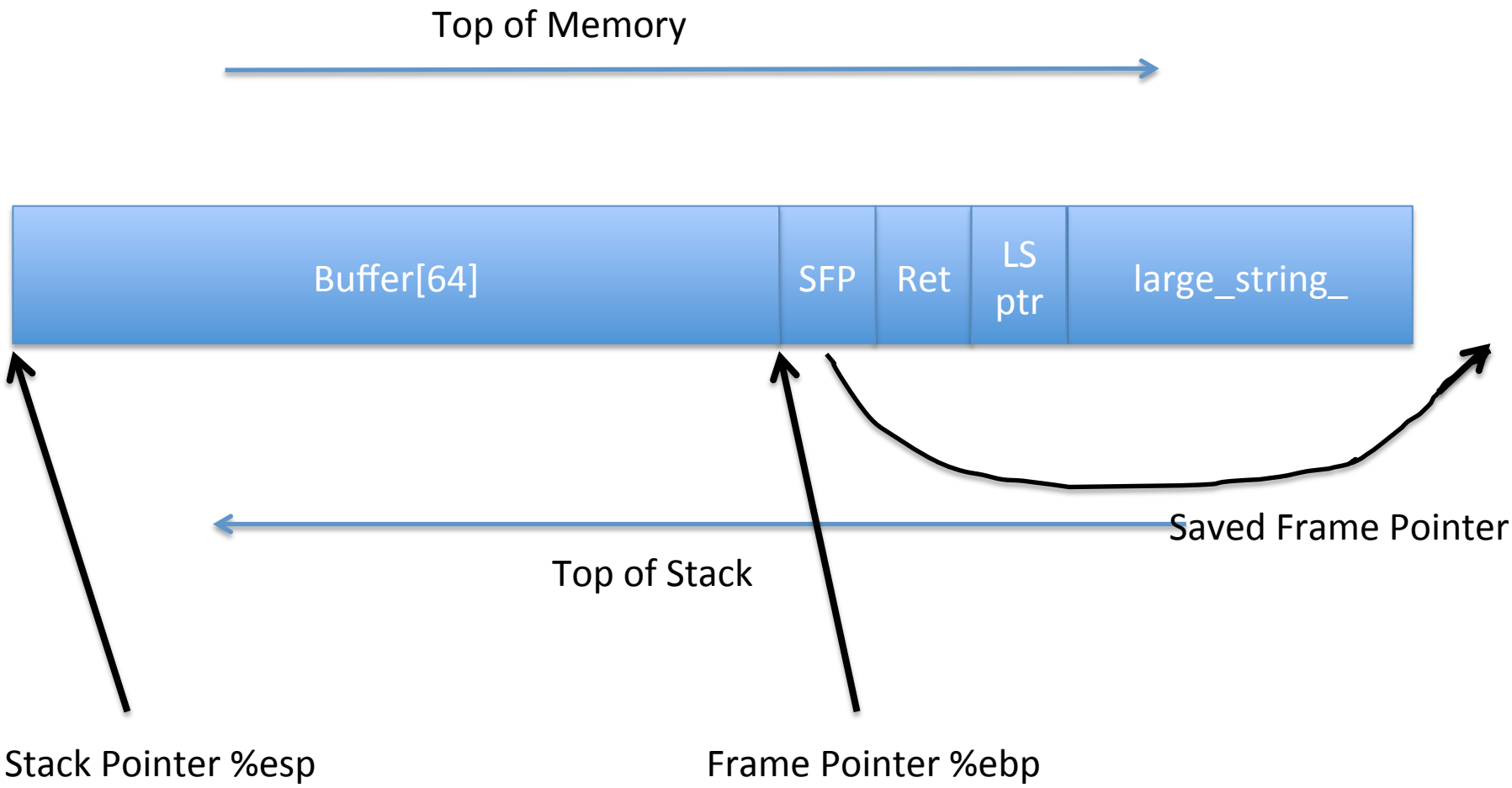


Example 2

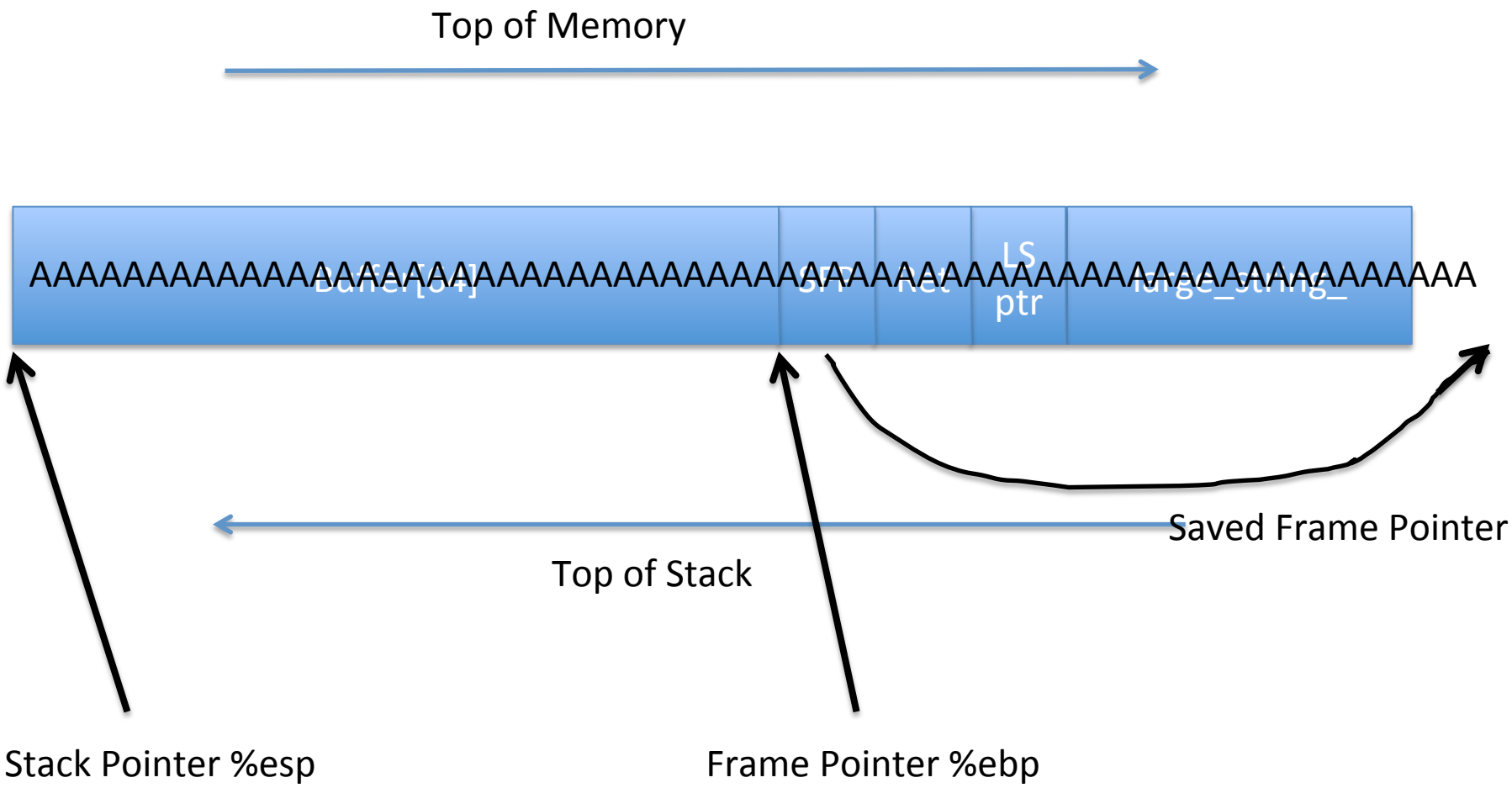
```
void myFunc(char *str)
{
  char buffer[64];
  strcpy(buffer, str);
}

int main(int argc, char* argv[])
{
  char large_string[256];
  int i;
  for( i = 0; i < 255; i++)
    large_string[i] = 'A';
  myFunc (large_string);
}
```

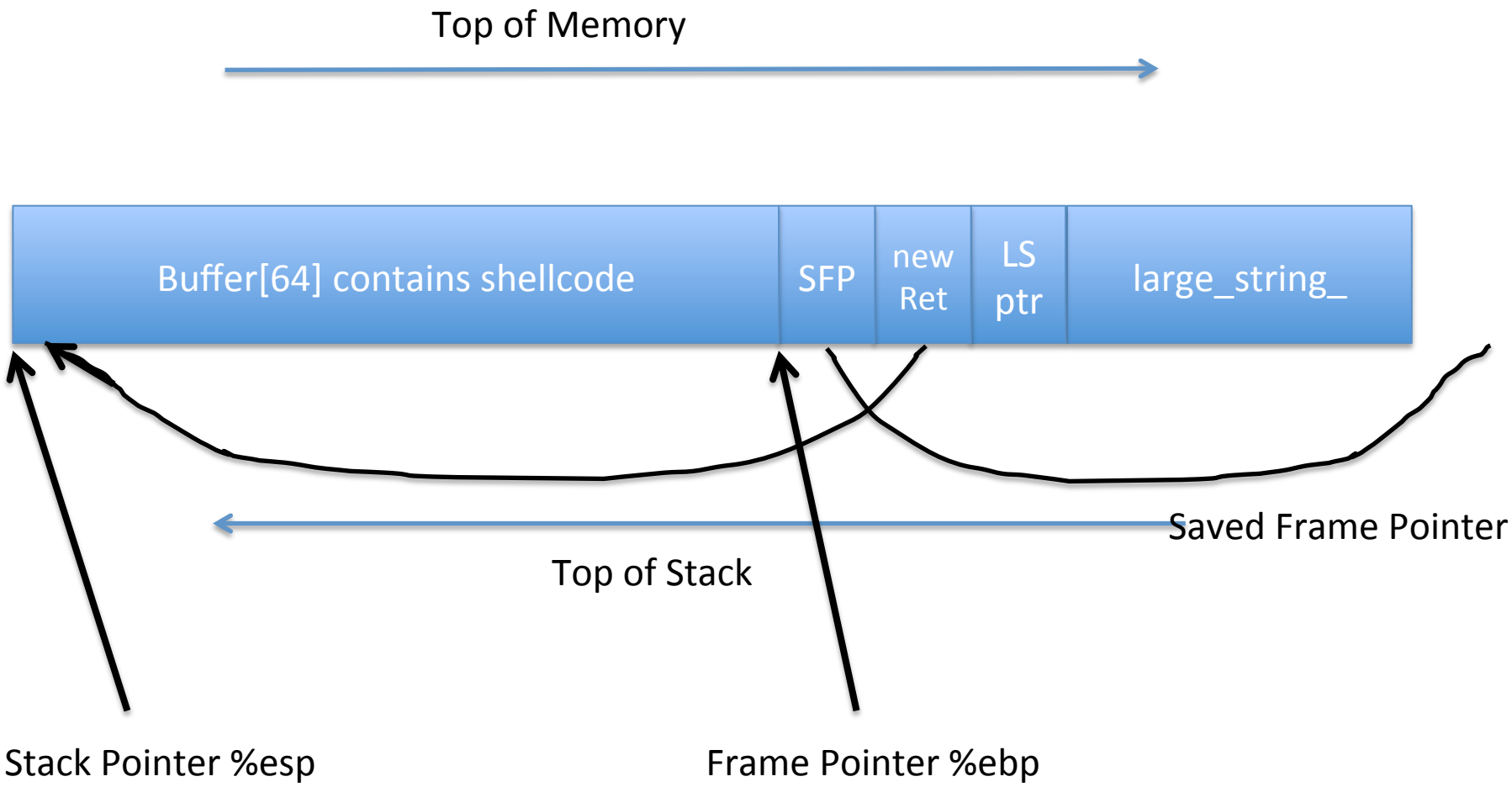
Stack in Example 2
right before strcpy()



Stack in Example 2 right after strcpy()



More Useful Stack for Attacker



Note similarity to System()

- Both cases it's channel mixing
  - ";" mixed with commands in shell language
  - Instruction pointers mixed with data
- Mixing control and data is frequently useful
  - But usually dangerous

Additional Readings

- Cowan et al: *StackGuard: Automatic Adaptive Detection and Prevention of Buffer-Overflow Attacks*
  - https://www.usenix.org/legacy/publications/library/proceedings/sec98/full_papers/cowan/cowan.pdf
- Shacham et al *On the Effectiveness of Address-Space Randomization*
  - http://www.cs.columbia.edu/~locasto/projects/candidacy/papers/shacham2004ccs.pdf
- Hovav Shacham *The Geometry of Innocent Flesh on the Bone*
  - http://cseweb.ucsd.edu/~hovav/dist/geometry.pdf