Defending Computer Networks
Lecture 2: Vulnerabilities

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Logistics

- Still space in class
- Restriction to CS M.Eng will be lifted shortly
- HW1 probably given out next time
- Website not up yet (my bad).

Main Goals for Today

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

Interesting News This Week

JPMorgan and Other Banks Struck by Hackers

A number of United States banks, including JPMorgan Chase and at least four others, were struck by hackers in a series of coordinated attacks this month, according to four people briefed on a continuing investigation into the crimes.

The hackers infiltrated the networks of the banks, siphoning off gigabytes of data, including checking and savings account information, in what security experts described as a sophisticated cyberattack.

The motivation and origin of the attacks are not yet clear, according to investigators. The F.B.I. is involved in the investigation, and in the past few weeks a number of security firms have been brought in to conduct studies of the penetrated computer networks.

Russian hackers attacked the U.S. financial system in mid-August, infiltrating and stealing data from **JPMorgan Chase & Co. (JPM)** and at least one other bank, an incident the FBI is investigating as a possible retaliation for government-sponsored sanctions, according to two people familiar with the probe.

http://www.nytimes.com/2014/08/28/technology/hackers-target-banks-including-jpmorgan.html

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

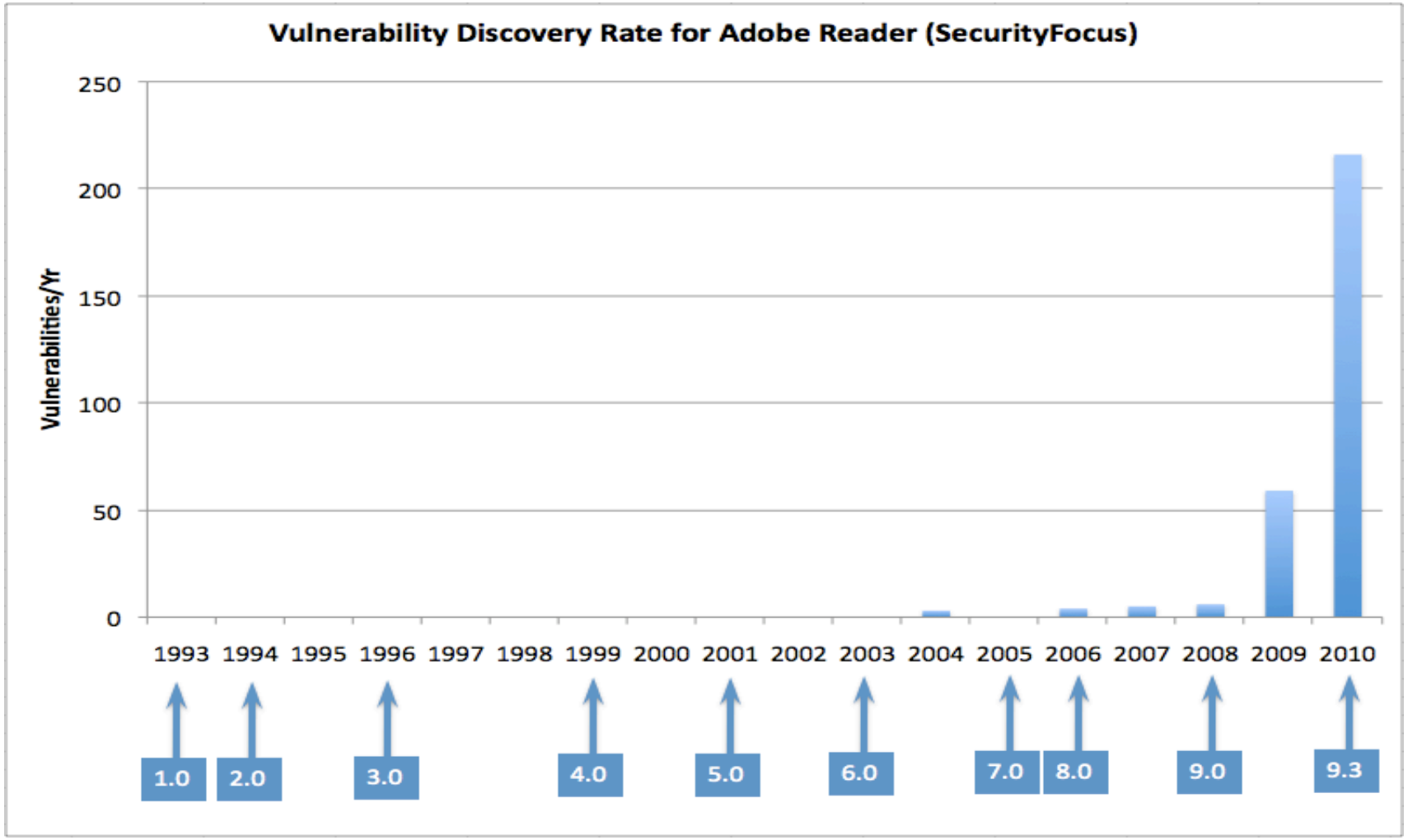
- When writing a server
  - Task is to mediate access to server's resources
  - Not grant arbitrary access
  - Have to be very careful in channeling
    - Constrained client-server protocol
    - To general-purpose OS/computer
- Attackers are evil/bad/smart/patient
- They are out to get you!


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
50
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
9.0
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

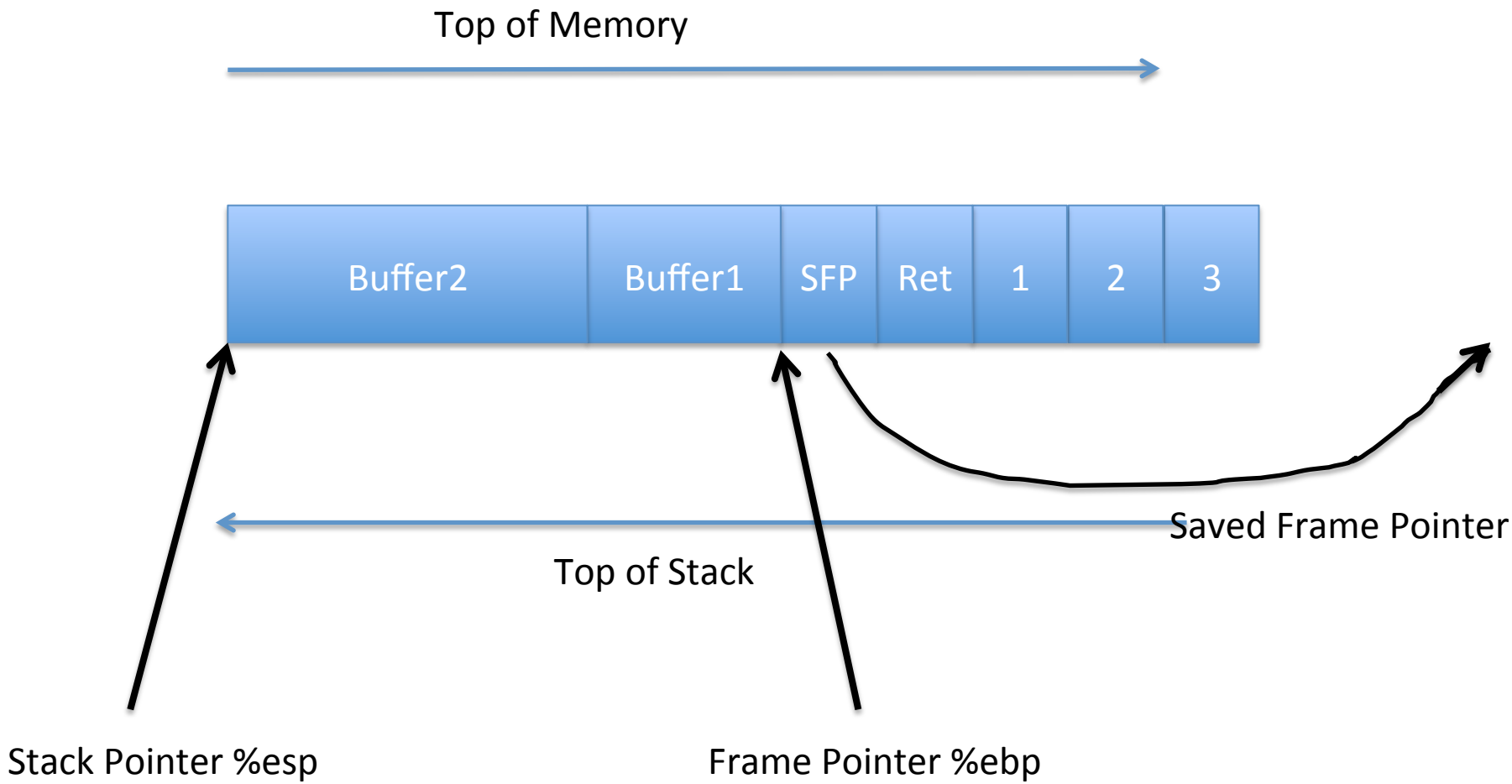
```
void myFunc(int a, int b, int c)
{
  char buffer1[5];
  char buffer2[10];
}

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

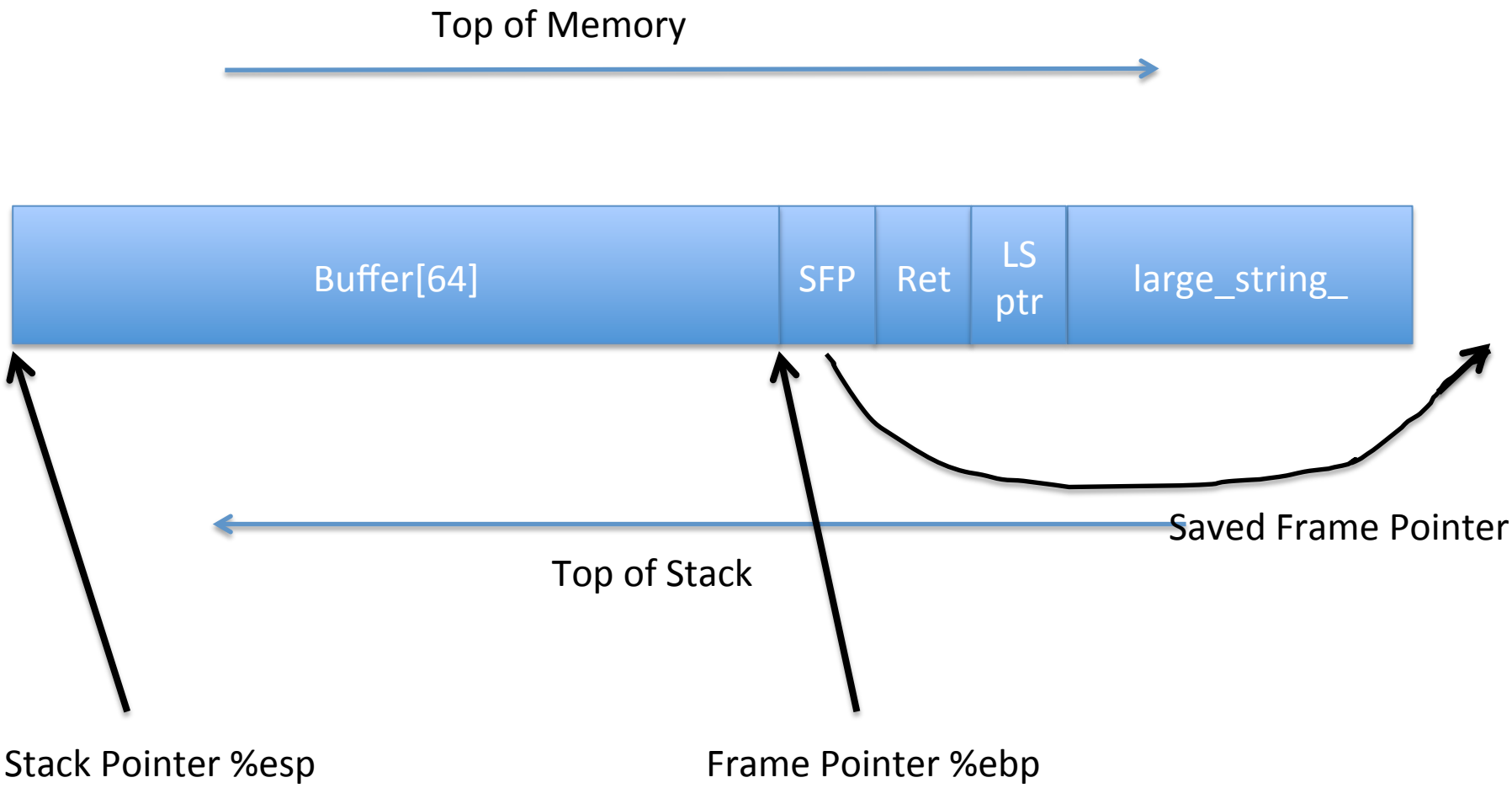


Example 2

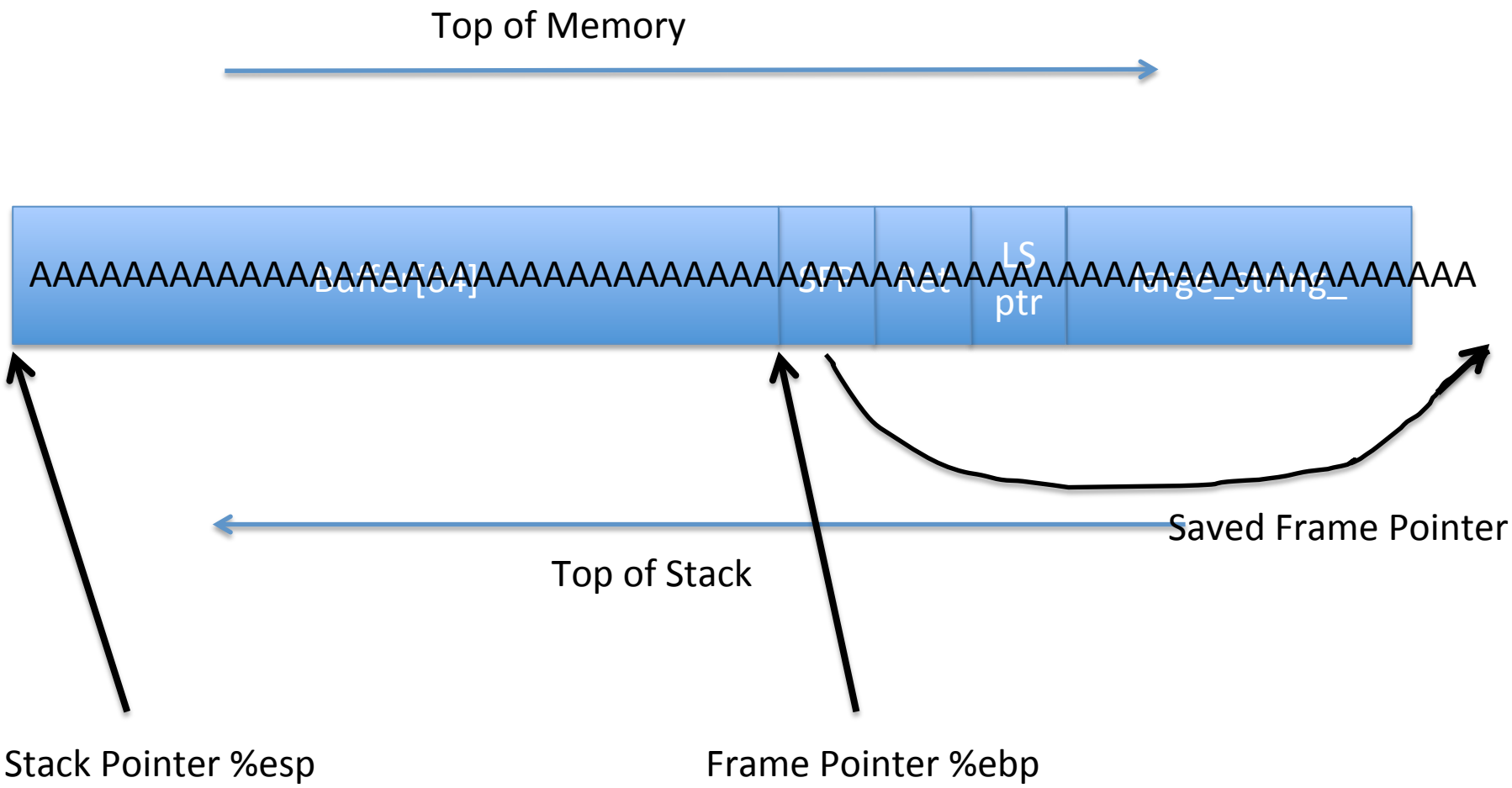
```
void myFunc(char *str)
{
  char buffer[64];
  strcpy(buffer, str);
}

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);
}
```

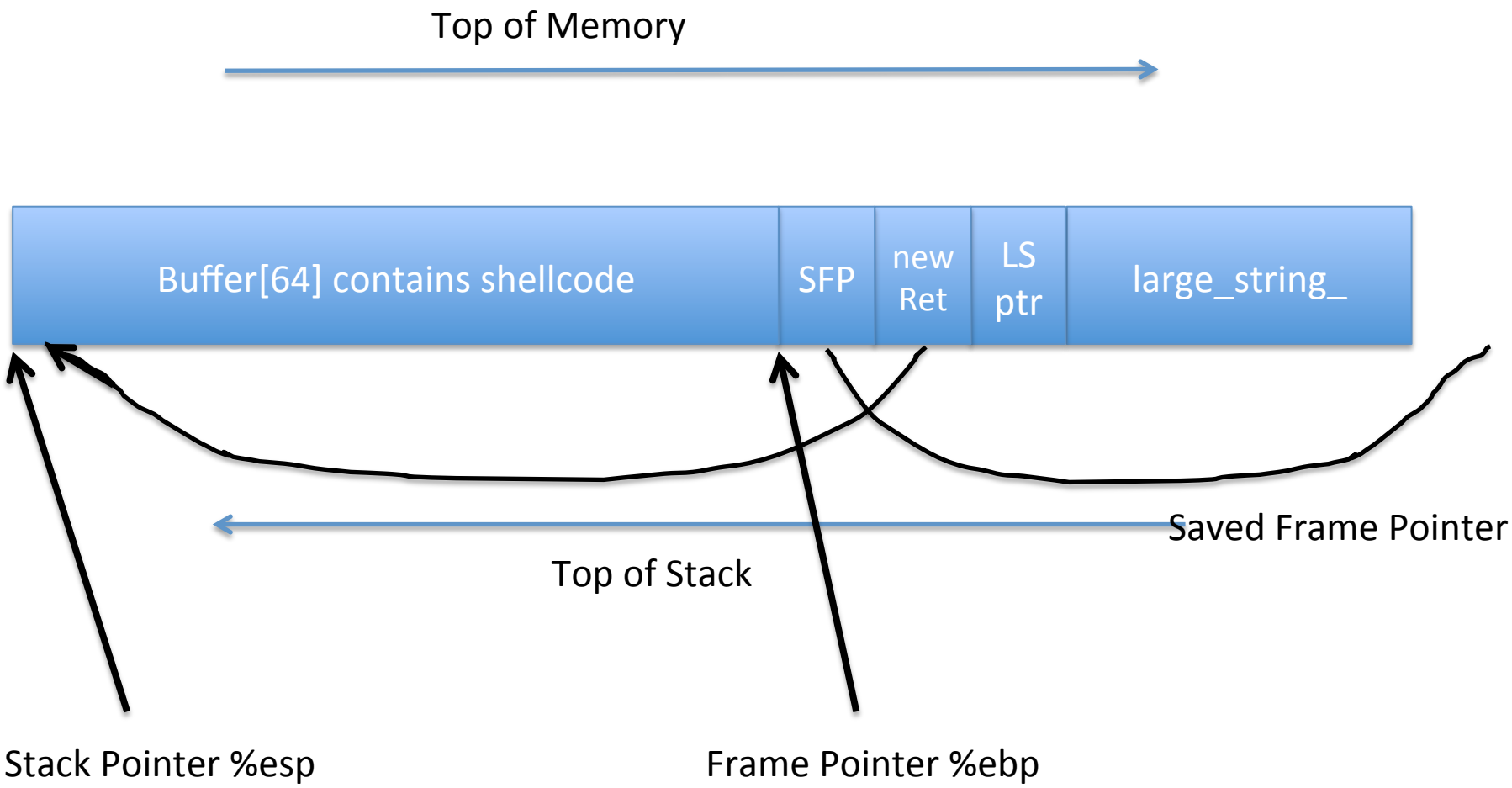
Stack in Example 2
right before strcpy()



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