CSCD 330
Network Programming
Spring 2017

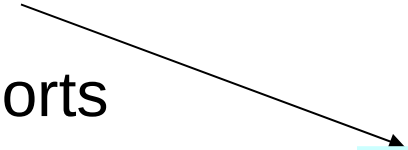
Lecture 6
Application Layer –
Socket Programming in Java

Reading for Java Client/Server see “Relevant Links”

Some Material in these slides from J.F Kurose and K.W. Ross

Chapter 2: Application Layer

- Principles of network applications
- Web and HTTP
- FTP (Skip)
- Electronic Mail
  - SMTP, POP3, IMAP
- DNS
- P2P Applications – As time permits
- Socket programming with TCP
  - Processes, Addresses and Ports
- Socket programming with UDP

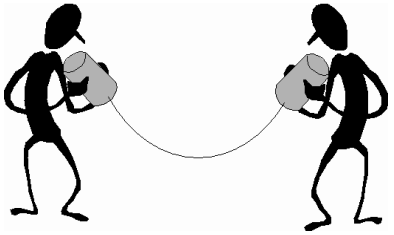


Today

Network Process Communication

Communication Between Hosts

- So, how do you “talk” to another host?
- What do you need to know?
  - Minimum
    - Name or Address of host
    - Agree on Protocol
  - Rely on Other Layers of Network
    - Lower layers to get message delivered



Addressing in Processes

- To receive messages, **process** running on a **host (machine)** must have identifier
  - Host device has unique 32-bit number

  IP address
    - Like: 146.187.134.22

- Question
  - Is IP address of host on which process runs enough for identifying the process?

Addressing in Processes

- NO, its not enough to have just host IP address
  - As we saw before, **146.187.134.22**

- **E**ach process must have its own identifier
  - Many processes can run on same host!!
  - What is the identifier called?

Addressing in Processes

- Process “identifiers” = Port Numbers
- Port Numbers
  - Standard way to uniquely identify processes
  - 16 bit numbers, from 1 – 65,535
  - Certain port numbers are **reserved** by the operating system
    - Port numbers below 1023 are reserved
    - Above 1023, anyone can use

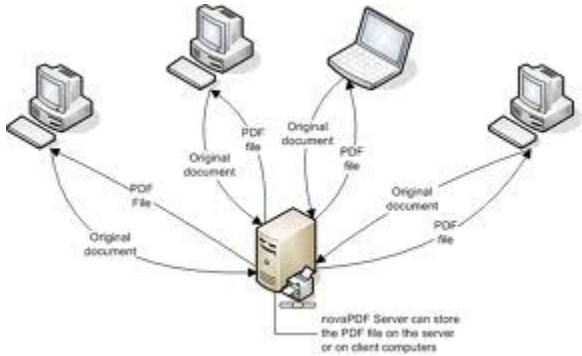
Reserved Numbers

http://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers

$ /etc/services Linux

C:\WINDOWS\system32\drivers\etc\services Windows

Addressing in Processes



Server Side

Well Known Port Numbers

- IP and port number of the server
- Well-known and advertised so client knows where to find service

Client Side

Ephemeral Port Numbers

- Port number on client side
- Generally allocated automatically by the kernel

Process Addressing

- Three Groups of Port Numbers
  - 1.Well Known Port Numbers 1 - 1023
    - IANA assigns port numbers to protocols have been standardized using RFC process
  - 2. Registered Port Numbers 1024 - 49151
    - Non-RFC Server Application can reserve one of these port numbers, through IANA
      - If approved, the IANA will register that port number and assign it to the application

Addressing in Processes

- Three Groups of Port Numbers
  - 3. Ephemeral Port Numbers 49152-65535
  - These ports are neither reserved nor maintained by IANA
  - Can be used for any purpose without registration, so they are appropriate for a private protocol, or temporary connection

Wireshark Capture Showing Ephemeral Ports

95	5.170696	72.14.213.100	192.168.0.199	HTTP	HTTP/1.1 200 OK (application/vnd.google.safebrowsing-chunk)
96	5.170713	192.168.0.199	72.14.213.100	TCP	41851 > http [ACK] Seq=1097 Ack=305 Win=6912 Len=0 TSV=946223 TSER=148
97	5.177997	192.168.0.199	72.14.213.100	HTTP	GET /safebrowsing/rd/ChFnb29nLXBoaXNoLXNoYXZhchAAGNemCCDYpggyBVcTAgAD
98	5.206723	72.14.213.100	192.168.0.199	TCP	[TCP segment of a reassembled PDU]
99	5.208667	72.14.213.100	192.168.0.199	HTTP	HTTP/1.1 200 OK (application/vnd.google.safebrowsing-chunk)
100	5.208692	192.168.0.199	72.14.213.100	TCP	41851 > http [ACK] Seq=2183 Ack=1941 Win=12608 Len=0 TSV=946232 TSER=1
101	8.902129	192.168.0.199	146.187.134.22	DNS	Standard query A www.hollywoodinsiders.net
102	8.982675	146.187.134.22	192.168.0.199	DNS	Standard query response CNAME p4-pprr.geo.premiumservices.yahoo.com CN
103	8.982998	192.168.0.199	216.39.62.191	TCP	46471 > http [SYN] Seq=0 Win=5840 Len=0 MSS=1460 TSV=947176 TSER=0 WS=
104	9.101005	216.39.62.191	192.168.0.199	TCP	http > 46471 [SYN, ACK] Seq=0 Ack=1 Win=5792 Len=0 MSS=1460 TSV=338412
105	9.101066	192.168.0.199	216.39.62.191	TCP	46471 > http [ACK] Seq=1 Ack=1 Win=5888 Len=0 TSV=947205 TSER=3384120
106	9.101200	192.168.0.199	216.39.62.191	HTTP	GET /holly.html HTTP/1.1
107	9.218219	216.39.62.191	192.168.0.199	TCP	http > 46471 [ACK] Seq=1 Ack=515 Win=6912 Len=0 TSV=3384121058 TSER=94
108	9.228880	216.39.62.191	192.168.0.199	HTTP	HTTP/1.1 304 Not Modified
109	9.228905	192.168.0.199	216.39.62.191	TCP	46471 > http [ACK] Seq=515 Ack=106 Win=5888 Len=0 TSV=947237 TSER=3384
110	9.229193	192.168.0.199	216.39.62.191	TCP	46471 > http [FIN, ACK] Seq=515 Ack=106 Win=5888 Len=0 TSV=947237 TSER
111	9.229337	216.39.62.191	192.168.0.199	TCP	http > 46471 [FIN, ACK] Seq=106 Ack=515 Win=6912 Len=0 TSV=3384121069

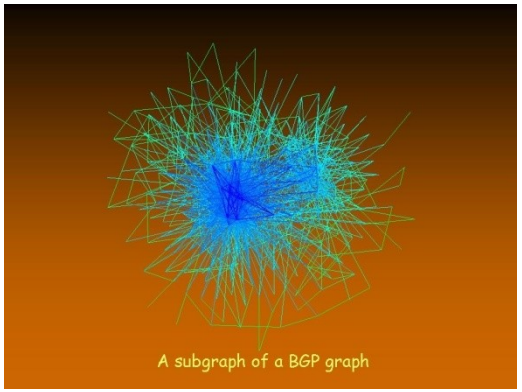
Process Addressing

- When you create a socket in Java, you associate it to a port number
- Called "**binding to a port**"
- So, unique identifiers for addressing a process on a given machine consist of:
  - IP address and port number
  - **Example:**

    To send HTTP message to gaia.cs.umass.edu web server:

    IP address: 128.119.245.12

    Port number: 80

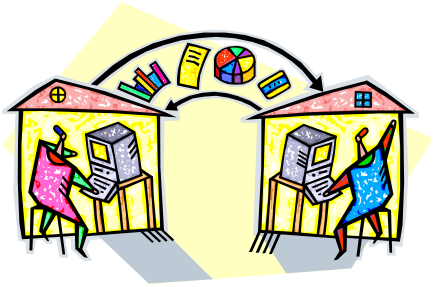


Client Server Programming in Java

Goal of Client/Server Programming

- What's the goal for applications in a networked environment?
  - Get information from my machine and move it to another machine or vice-versa
  - Similar to reading and writing files

    Except ... files exist on a remote machine
  - Network programming in a nutshell !!!



What is a socket?

- A socket , software abstraction used to represent the "terminals" of a connection between two machines – like electric socket
- For a given connection
  - Socket on each machine and
  - A hypothetical "cable" running between two machines
  - Each "cable" end plugs into socket
  - Physical hardware and cabling between machines unknown and not needed for communication
  - Its an abstraction … !!!!!

Socket programming

Goal Learn to build client/server applications that communicate using sockets

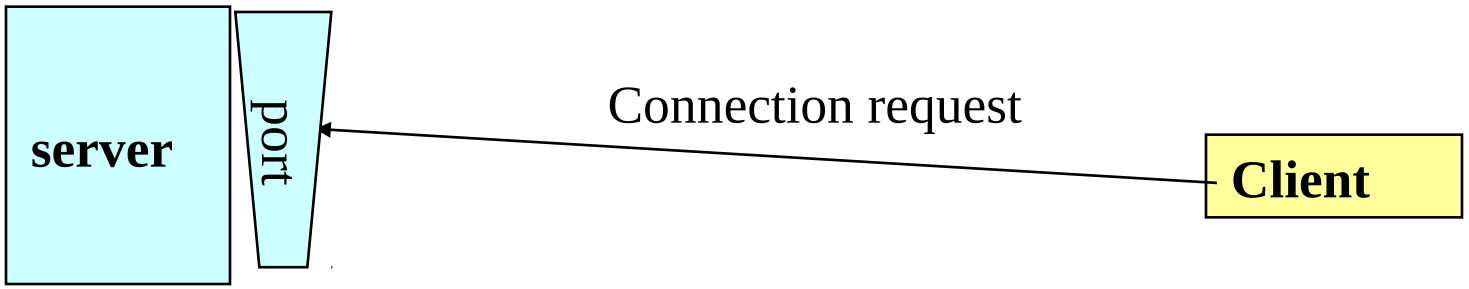
Socket API

- TCP/IP Stack funded by ARPA
  - Resides in Operating System
- Needed an API into stack
- Introduced **BSD 4.1 UNIX, 1981**

- Two types of transport service supported by the socket API:
  1. Unreliable - UDP
  2. Reliable – TCP

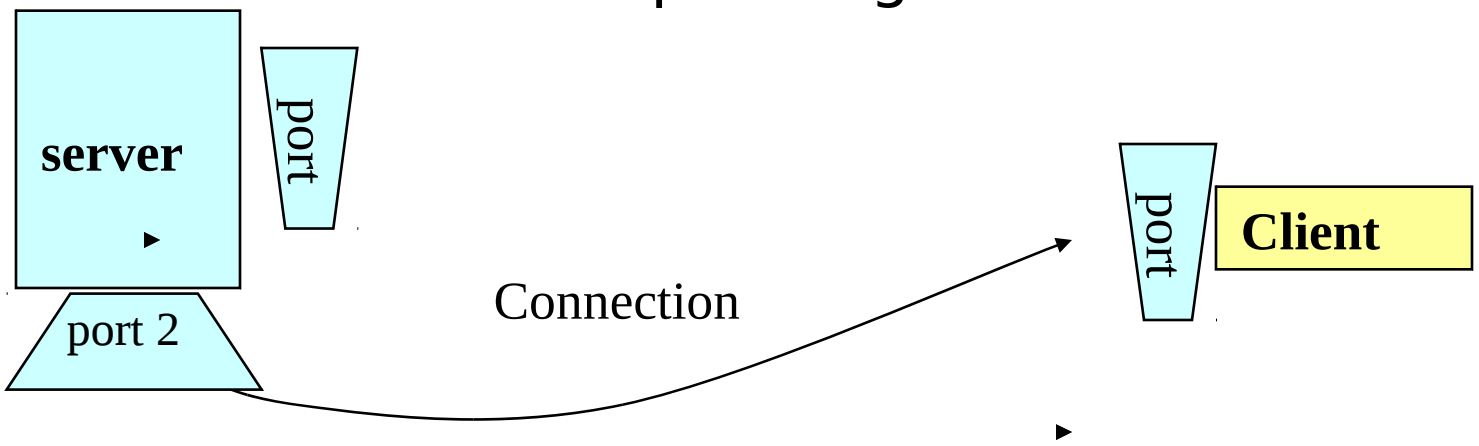
Socket Communication

- A server (program) runs on a specific computer and has a socket that is bound to a specific port
- Server waits and listens to socket for a client to make a connection request



Socket Communication

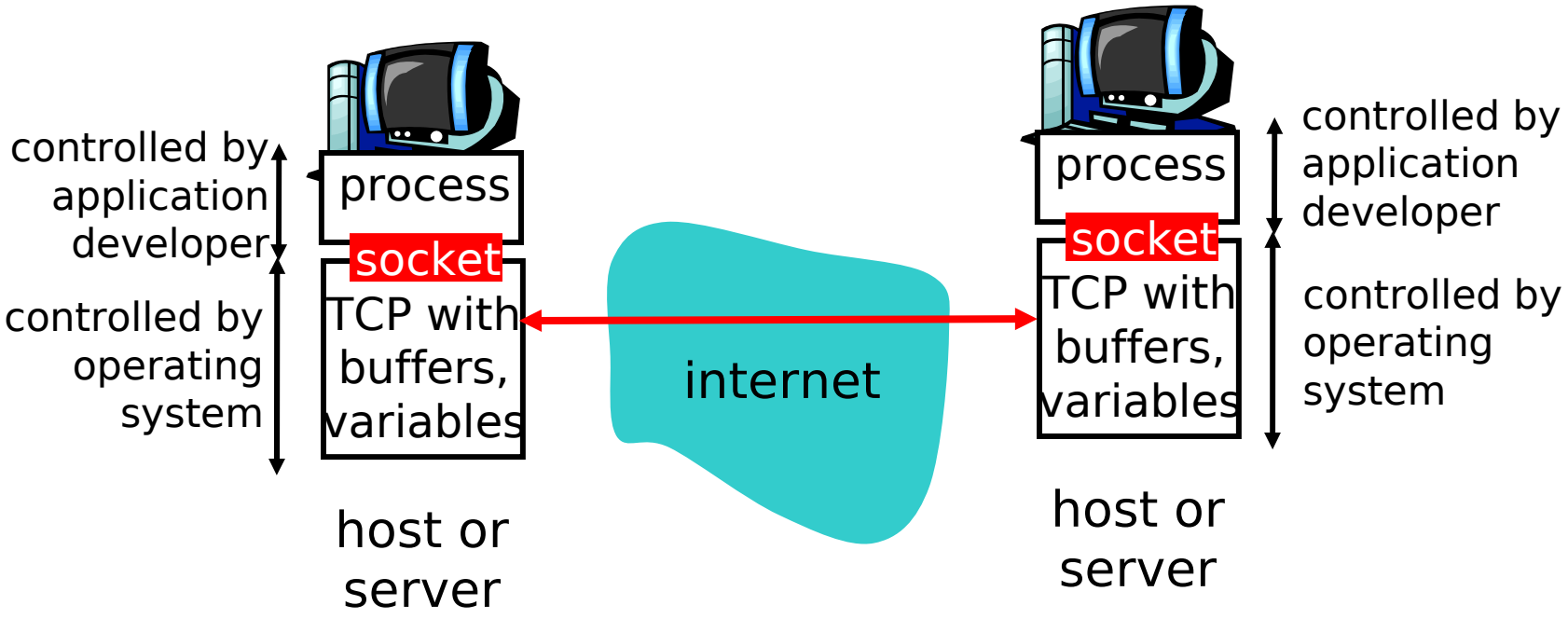
- If everything goes well, server accepts connection
- Upon acceptance, server gets new socket bound to a different port
- Needs a new socket (consequently a different port number) so that it can continue to listen to the original socket for connection requests while serving the connected client
- New socket is for responding back to the client



Socket Programming Using TCP

Socket: Door between application process and end-end-transport protocol (UDP or TCP)

TCP Service: reliable transfer of **bytes** from one process to another



Socket Programming Using TCP

Client must first create a connection to server before sending data!!

Client must contact server

- Server process must **first** be running
- Server must have created socket (door) that welcomes client's contact

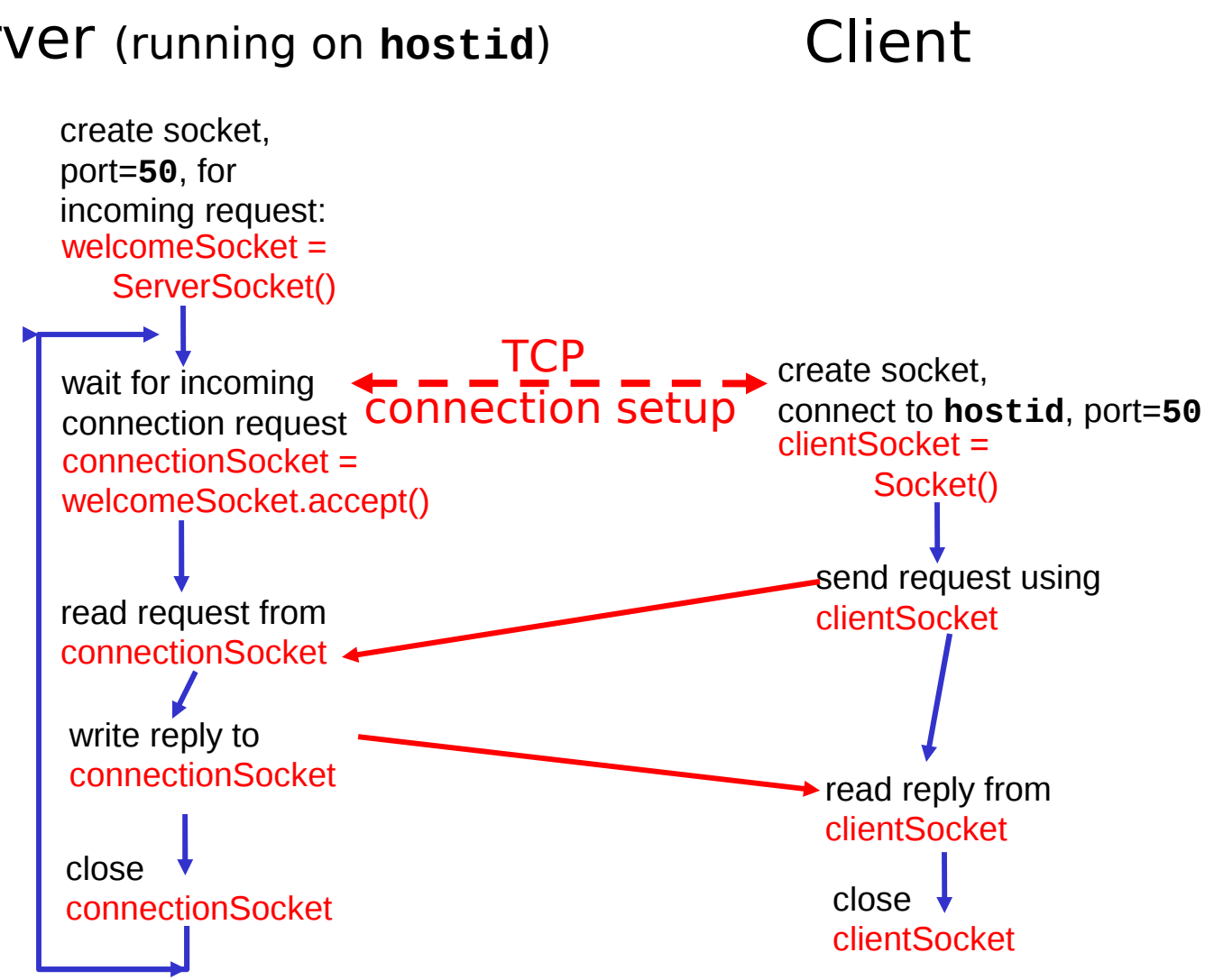
Client contacts server by

- Creating client-side TCP socket
- Specify IP address, port number of server process
- When client creates socket: client TCP establishes connection to server TCP

Socket Programming Using TCP

- **When contacted by client,**
  - TCP Server creates new socket
  - Does this for each client
  - Allows server to talk with multiple clients
  - Source port numbers used to distinguish clients

Client/Server socket interaction: TCP



Stream jargon

- A stream sequence of characters that flow into or out of a process
- An input stream attached to some input source for the process, e.g., keyboard or socket.

- An output stream attached to an output source, e.g., monitor or socket.

Socket Programming with TCP

Example: Uppercase Converter

1) Client reads line from standard input **inFromUser** stream, sends to server via socket **outToServer** stream
2) Server reads line from socket
3) Server converts line to uppercase, sends back to client
4) Client reads, prints modified line from socket **inFromServer** stream

Client Side Character Converter

- First, we will look at code for the Client side of the Upper Case Converter …..
- Next slide define some Java Socket characteristics client side

Java Socket programming with TCP

- java.net.socket
- Socket object is Java representation of TCP connection
  - When socket created on the client side, a connection is opened to a destination
- Methods
  - Two most important methods

    getInputStream() and getOutputStream()
  - Return stream objects used to communicate through the socket
  - The close() method tells underlying operating system to terminate the connection

Client Uppercase Converter

- **Code Logic**
  - Accept a string to be converted from the keyboard
  - Attach to a Uppercase Server via socket
  - Send the string through the socket
  - Read the string back from the socket
  - Print the string to the terminal
  - Close the connection

Example: Java client (TCP)

```
import java.io.*;
import java.net.*;
class TCPClient {

    public static void main(String argv[]) throws Exception
    {
        String sentence;
        String modifiedSentence;

        BufferedReader inFromUser =
          new BufferedReader(new InputStreamReader(System.in));

        Socket clientSocket = new Socket("hostname", 6789);

        DataOutputStream outToServer =
          new DataOutputStream(clientSocket.getOutputStream());
```

Keyboard

Create input stream

Create client socket, connect to server

Create output stream attached to socket

Example: Java client (TCP), cont.

Create input stream attached to socket

```
BufferedReader inFromServer =
  new BufferedReader(new
  InputStreamReader(clientSocket.getInputStream()));

sentence = inFromUser.readLine();
```

Input from Keyboard

Send line to server

```
outToServer.writeBytes(sentence + '\n');
```

Read line from server

```
modifiedSentence = inFromServer.readLine();

System.out.println("FROM SERVER: " + modifiedSentence);

clientSocket.close();

    }
}
```

Java Server (TCP)

- ServerSocket represents listening TCP connection
  - Once an incoming connection is requested,
  - ServerSocket object will return a Socket object representing the connection

- Methods
  - Most important method is accept()
  - Returns a Socket, connected to a client
  - The close() method tells operating system to stop listening for requests on the socket
  - Other Methods are also provided

Server Uppercase Converter

- **Code Logic**
  - Set up a ServerSocket
  - Listen for a client on the ServerSocket and spawn a new socket for the client
  - Attach input and output streams to new socket
  - Read the string from the socket and convert it to uppercase
  - Send it the uppercase string through the socket
  - Close the connection to the new socket
  - Return to listening for a new client

Example: Java server (TCP)

```
import java.io.*;
import java.net.*;

class TCPServer {

  public static void main(String argv[]) throws Exception
   {
     String clientSentence;
     String capitalizedSentence;

     ServerSocket welcomeSocket = new ServerSocket(6789);

     while(true) {

       Socket connectionSocket = welcomeSocket.accept();

       BufferedReader inFromClient =
         new BufferedReader(new
         InputStreamReader(connectionSocket.getInputStream()))
```

Create welcoming socket at port 6789

Waits, on welcoming socket for contact by client

Create input stream, attached to socket

Example: Java server (TCP), cont

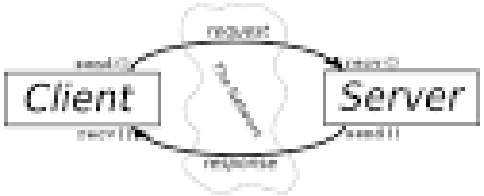
Create output stream, attached to socket

Read in line from socket

Write out line to socket

```
DataOutputStream  outToClient =
new DataOutputStream(connectionSocket.getOutputStream());

clientSentence = inFromClient.readLine();

capitalizedSentence = clientSentence.toUpperCase() + '\n';

outToClient.writeBytes(capitalizedSentence);

connectionSocket.close ();
        }
    }
}
```

End of while loop, loop back and wait for another client connection



Running the Client/Sever

Example of Server Creating Socket Object

- Here is a TCP Server that listens on a port for a connection, and creates a “socket” object for talking to client
- Has Ephemeral port numbers
- Can use telnet to play the role of a client
- Steps:

1. Start my Server: java HelloServera 5555

I can connect simply to it to show server ports to client

2. telnet localhost 5555

Or, I can use a client that shows ports on client side too

3. Can also use: java HelloClient 5555

Java .net Package

Java Sockets Programming

- The package java.net provides support for socket programming (and more).

- Typically you import everything defined in this package with:

import java.net.*;

Classes

InetAddress

Socket

ServerSocket

DatagramSocket

DatagramPacket

InetAddress class

- Static methods you can use to create new InetAddress objects.
  - getByName(String host)
  - getAllByName(String host)
  - getLocalHost()

InetAddress addr =

InetAddress.getByName(“www.ewu.edu”);

- Throws **UnknownHostException**

Sample Code: Lookup.java

- Uses InetAddress class to lookup hostnames found on command line.

> java Lookup www.ewu.edu

www.ewu.edu: 146.187.224.198

> java Lookup www.yahoo.com

www.yahoo.com: 209.131.36.158

Lookup.java Code

```
try {
  InetAddress a = InetAddress.getByName(hostname);
  System.out.println (hostname + ":" +  a.getHostAddress());
} catch (UnknownHostException e) {
  System.out.println("No address found for " +   hostname);
}
```

Server Classes

- Two classes of socket used for TCP
  1. java.net.ServerSocket class
     - Used by server applications to obtain port and listen for client requests
     - **ServerSocket class – some constructors**

       public ServerSocket(int port) throws IOException
       - Attempts to create a server socket bound to specified port. An exception happens if port is already bound by another application

       public ServerSocket(int port, int backlog) throws IOException
       - Similar to previous constructor, backlog parameter specifies how many incoming clients to store in wait queue

Server Classes

- Here are common methods of ServerSocket class:

  public Socket accept() throws IOException

  - Waits for an incoming client.
  - Method blocks until either client connects to server on specified port or socket times out, assuming at time-out value has been set using setSoTimeout() method. Otherwise, this method blocks indefinitely

  public void setSoTimeout(int timeout)

  - Sets time-out value for how long the server socket waits for a client during accept()

Server and Client Class

2. java.net.Socket class is socket

   both client and server use to communicate

   - Client obtains Socket object by instantiating one
   - Server obtains Socket object from return value of accept() method

   • Constructor:

   public Socket(String host, int port) throws UnknownHostException, IOException

   • This method attempts to connect to specified server at specified port

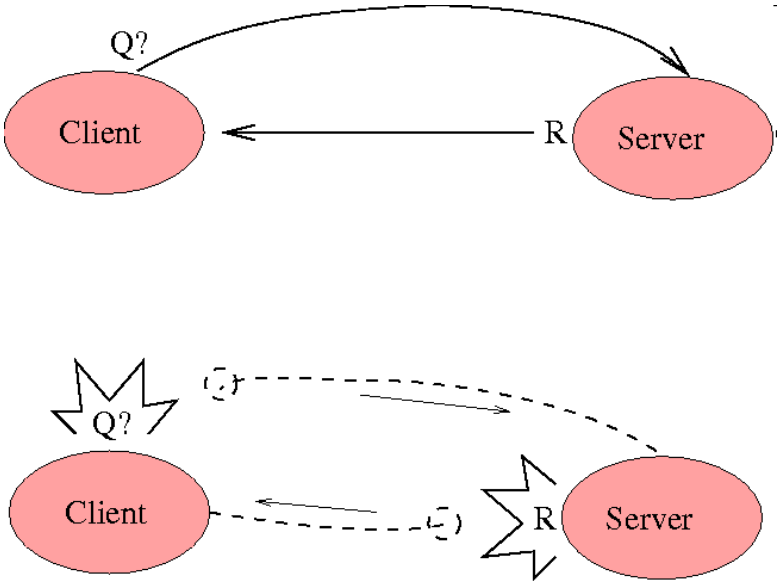
   • If this constructor does not throw an exception, connection is successful and client is connected to server

Server and Client Class

- Two most important methods of Socket class are:
  - public InputStream getInputStream() throws IOException
    - Returns input stream of socket
    - Input stream is connected to the output stream of the remote socket
  - public OutputStream getOutputStream() throws IOException
    - Returns output stream of the socket
    - Output stream is connected to input stream of remote socket

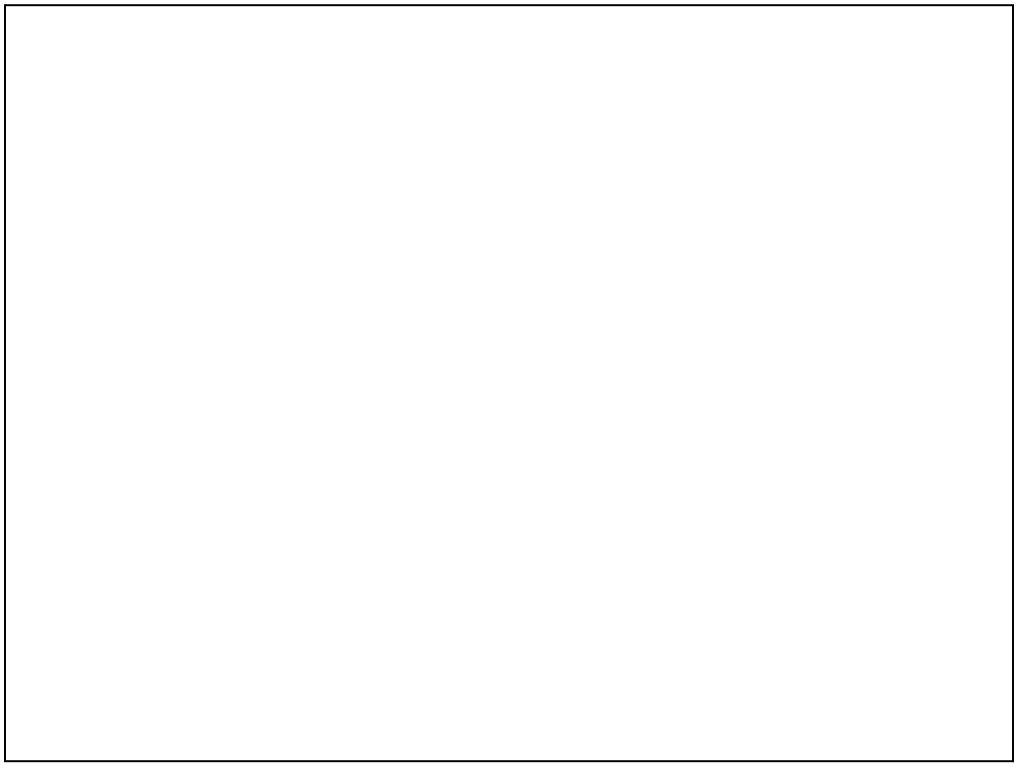
Summary

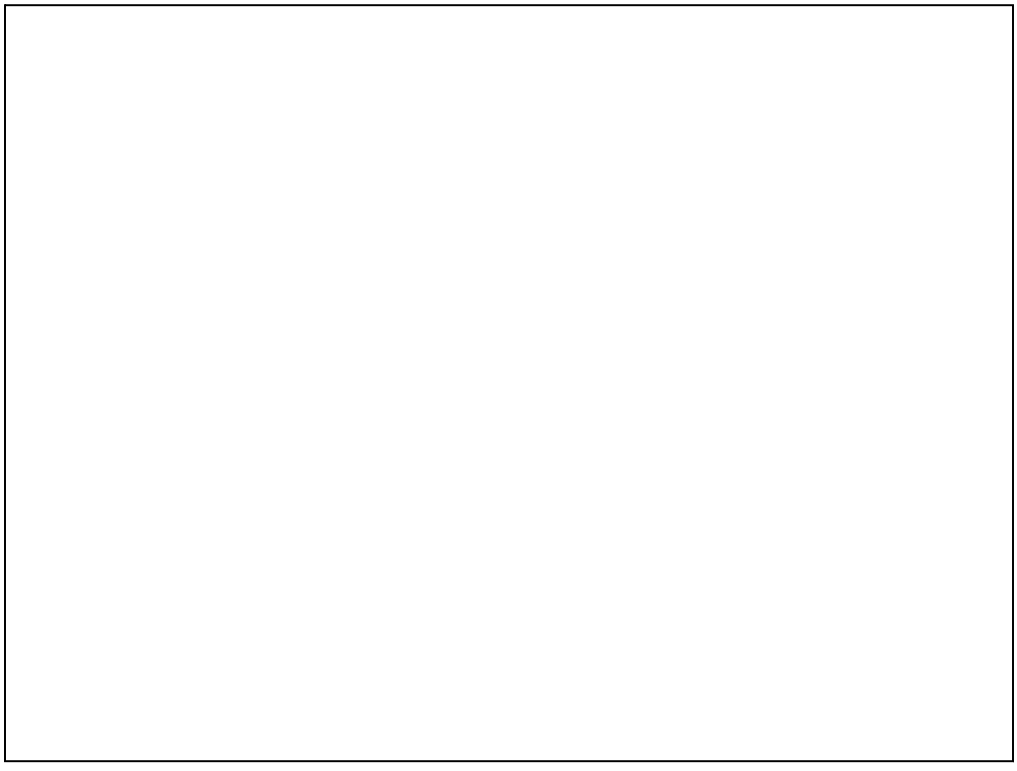
- Covered briefly, client-server programming in Java environment
- Uses sockets – virtual pipe connections across the Internet
- Allows you to abstract away the details of the network layers (to a large degree)
- Lets you read/write data to processes on local or very remote hosts
- Can get very complicated in functionality
- Will explore more complicated client/server applications in programming assignments

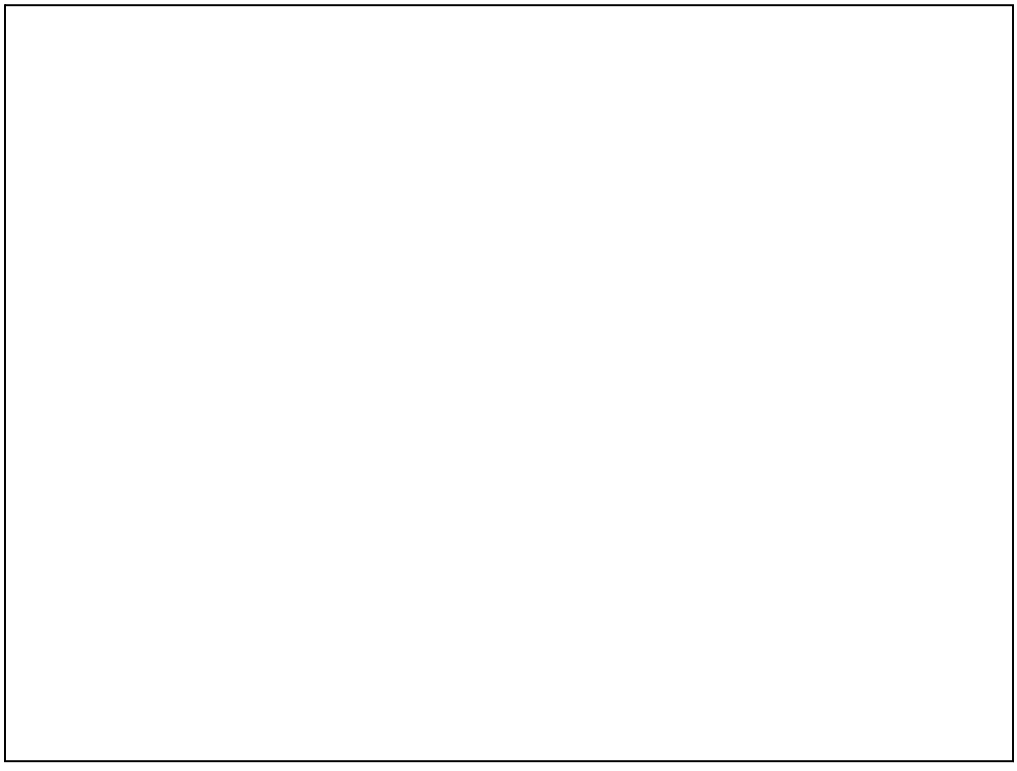


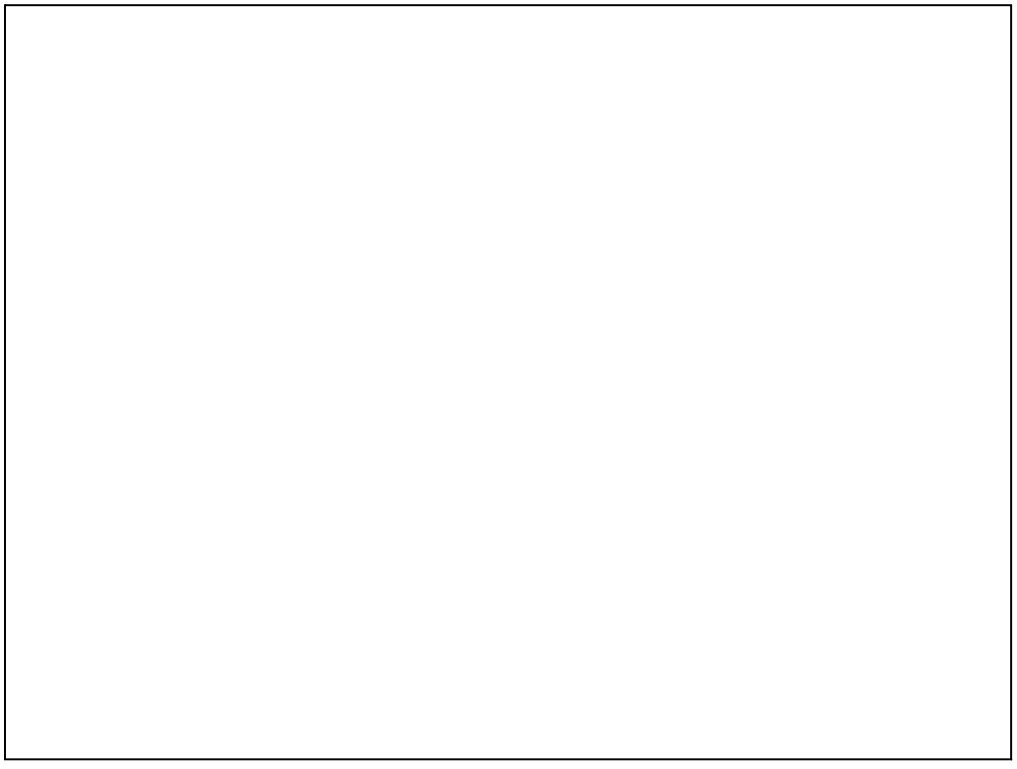
Next … Java UDP Sockets

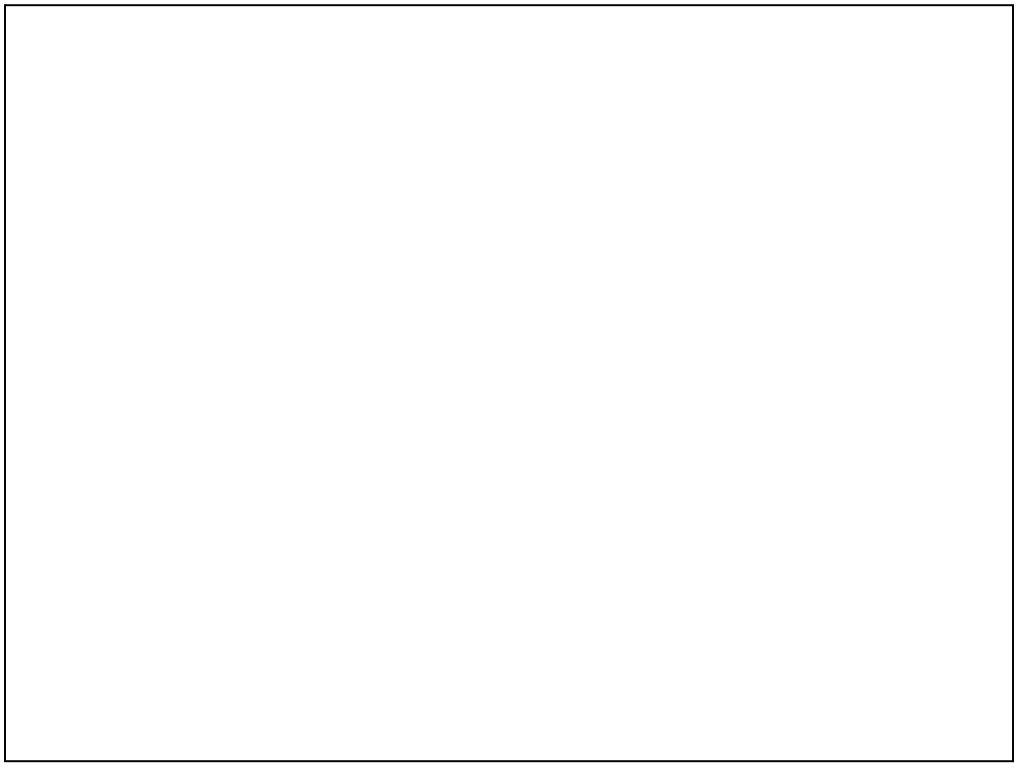
End

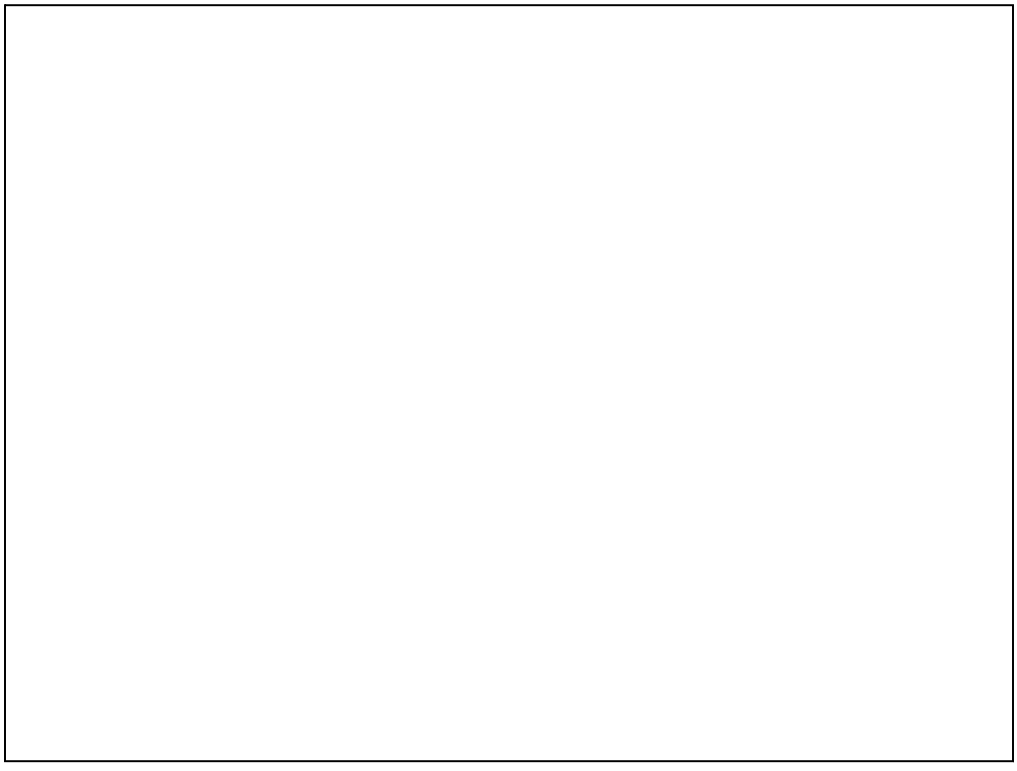


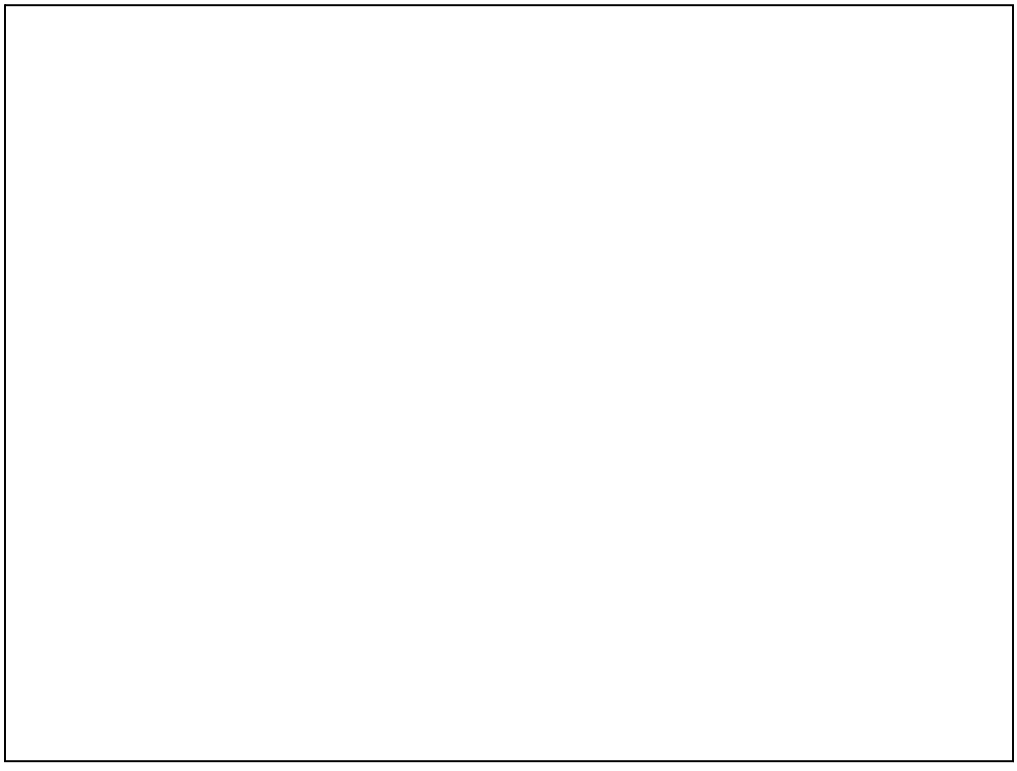


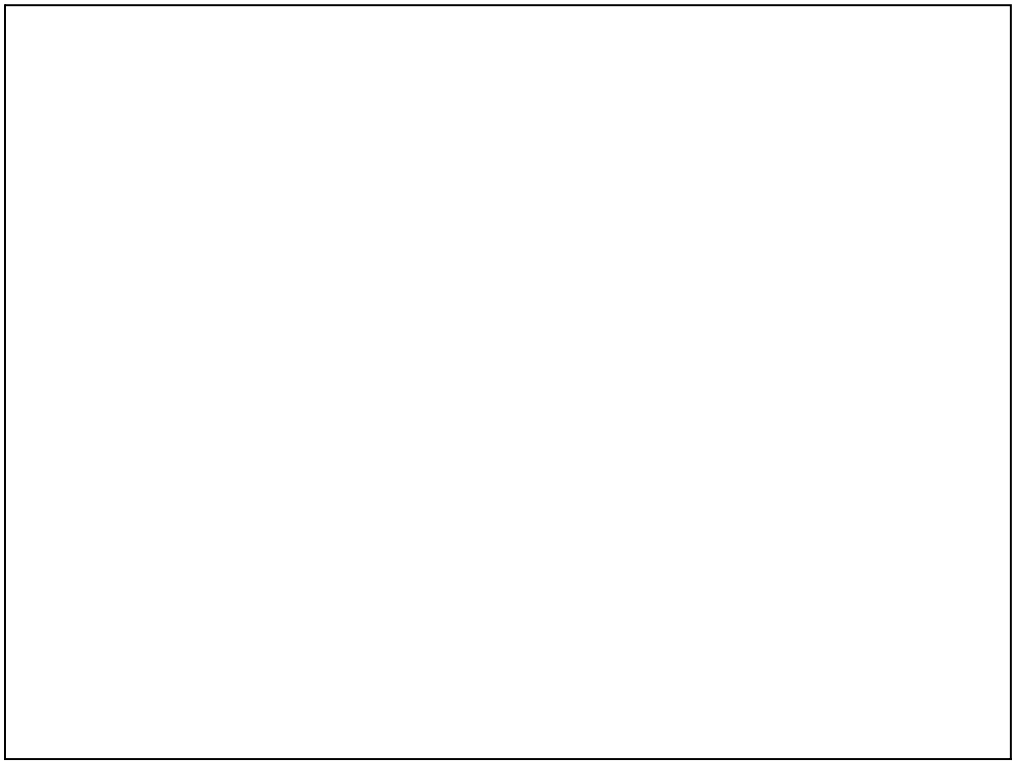


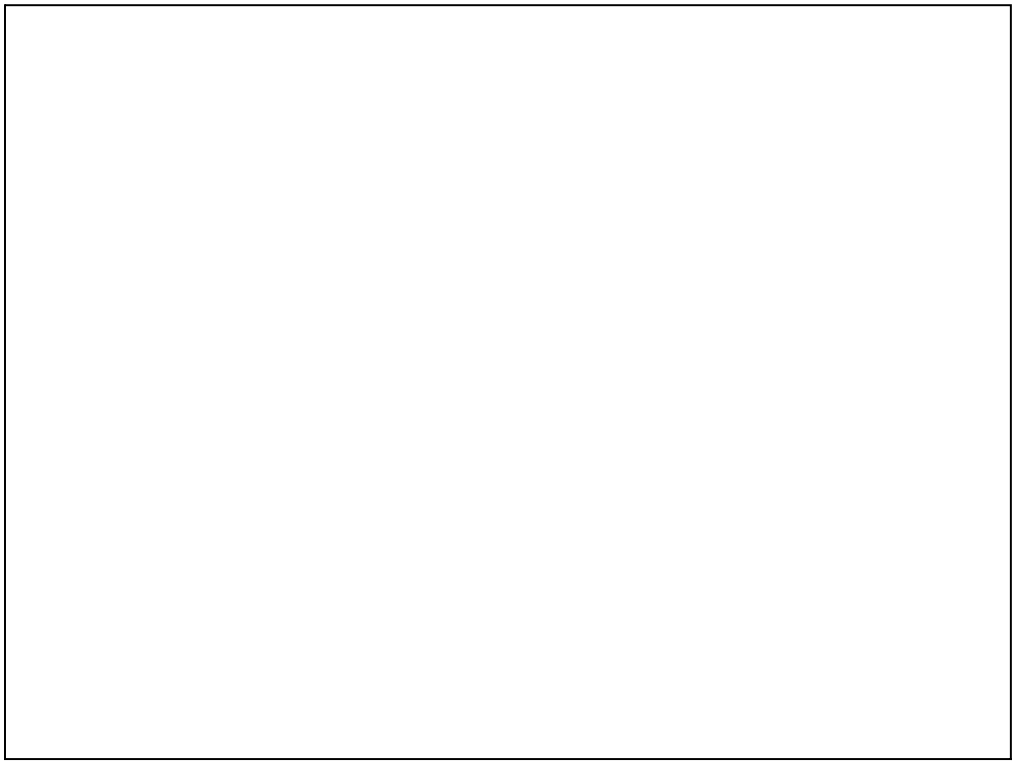


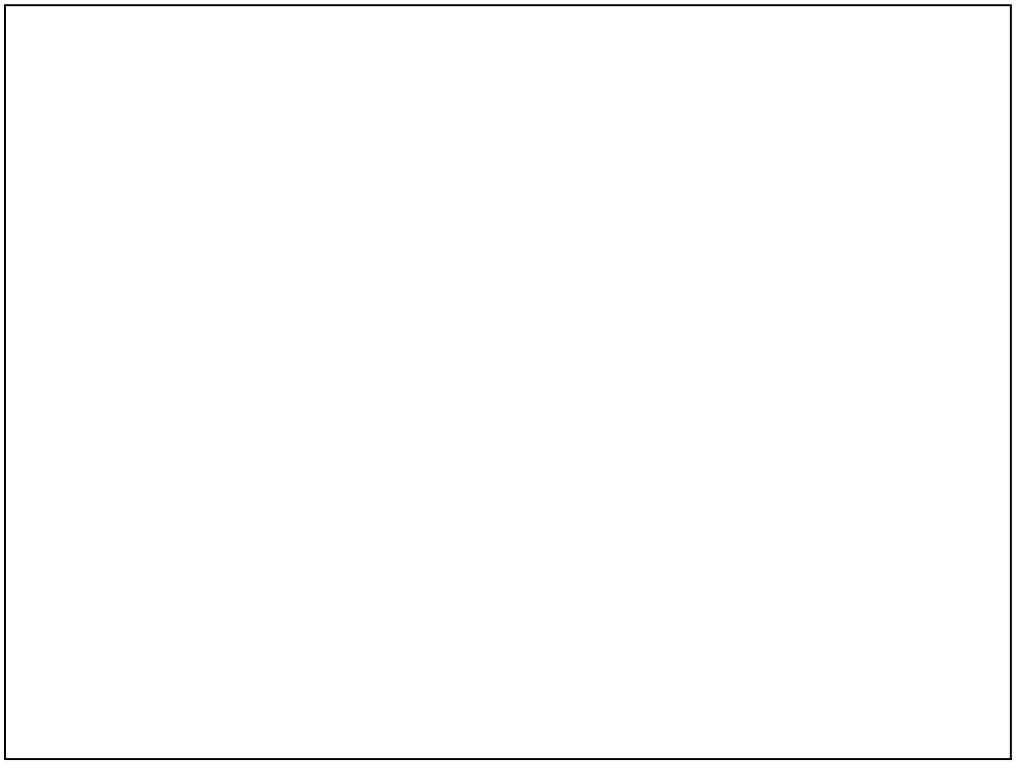


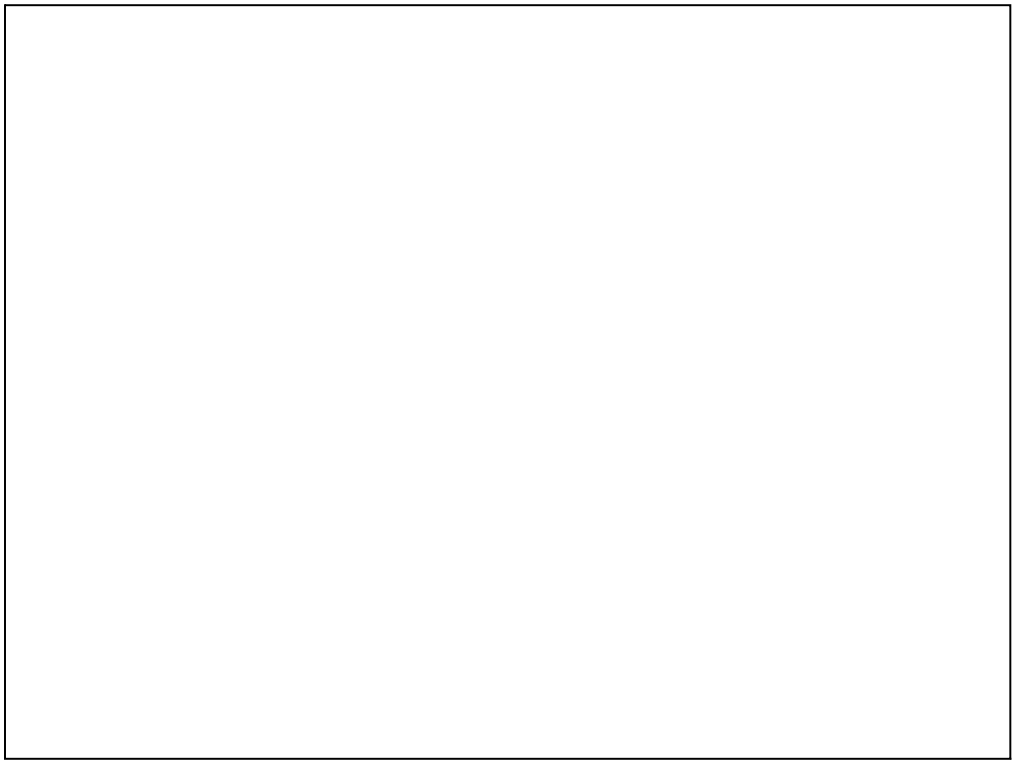


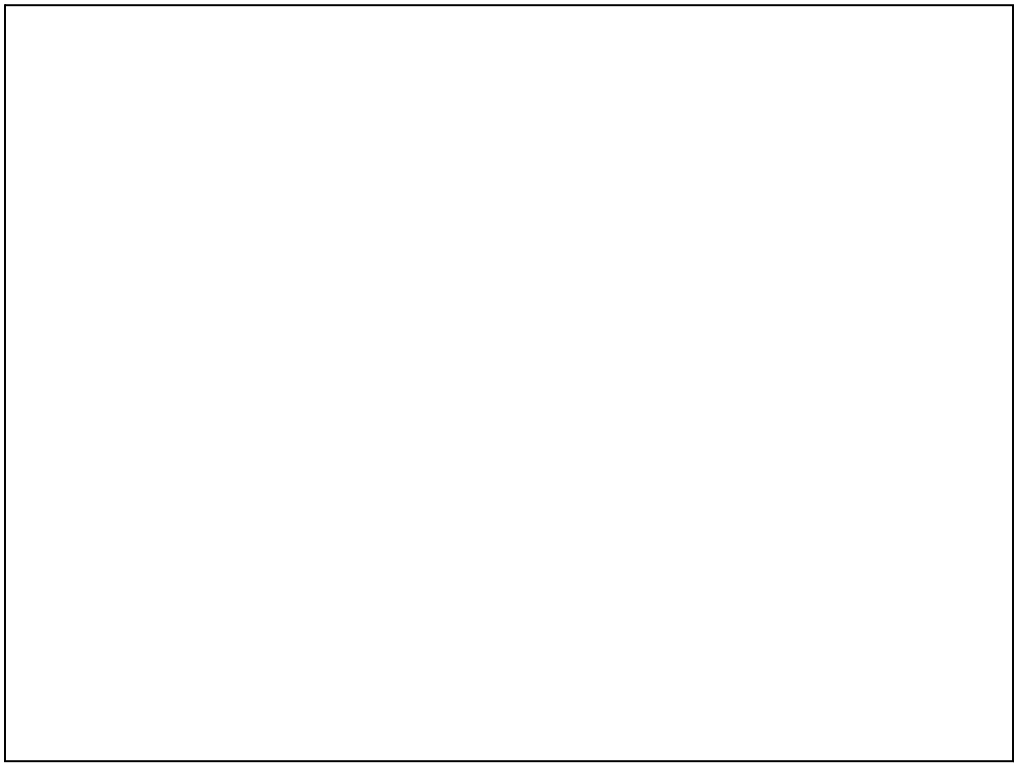


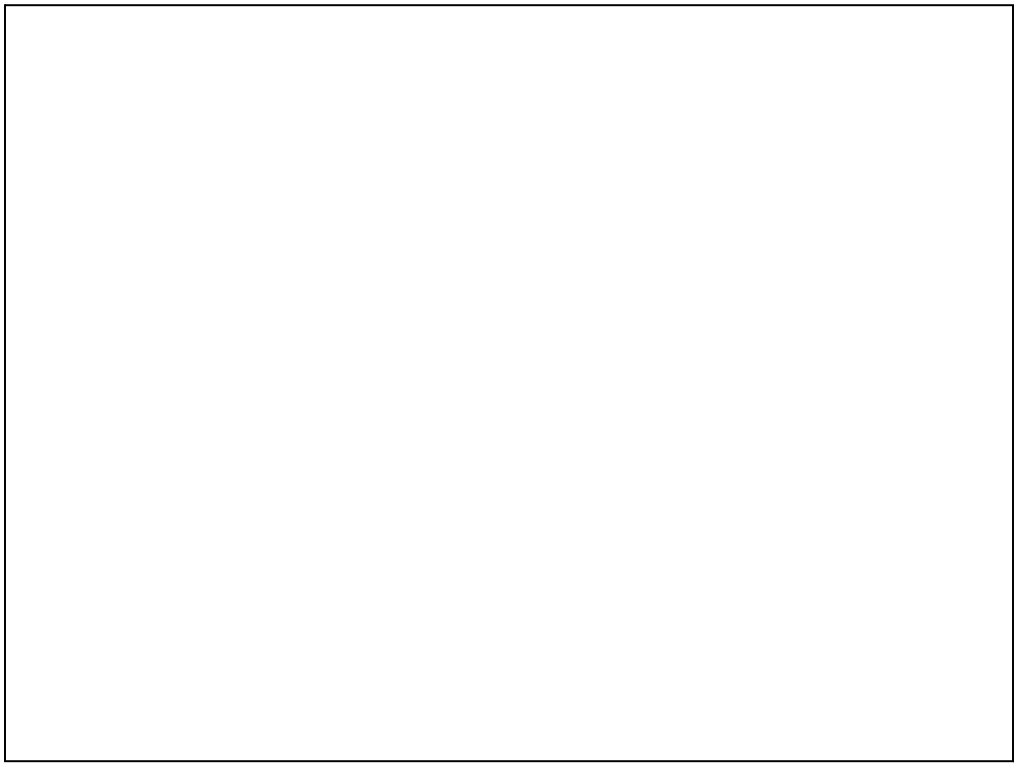


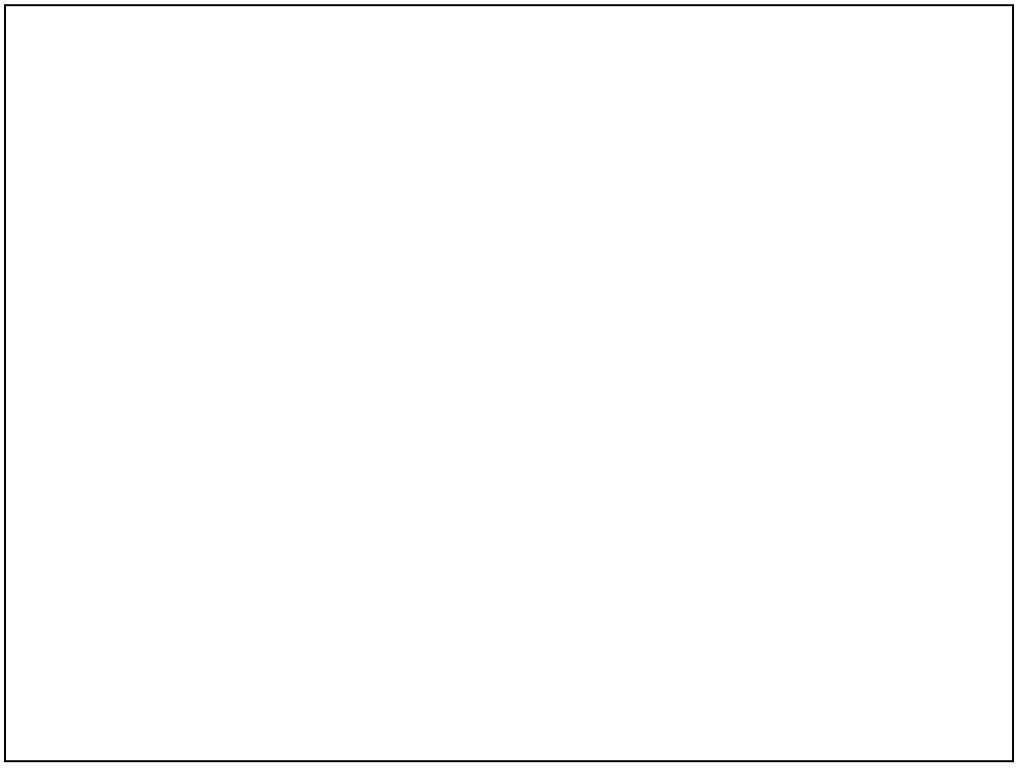


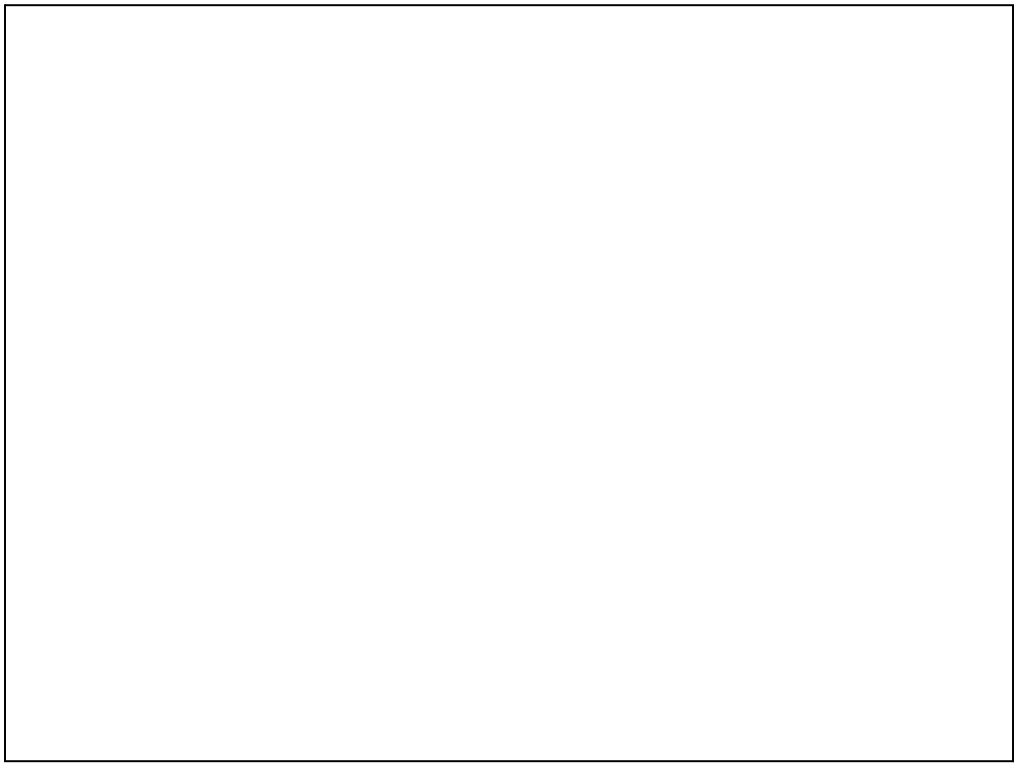


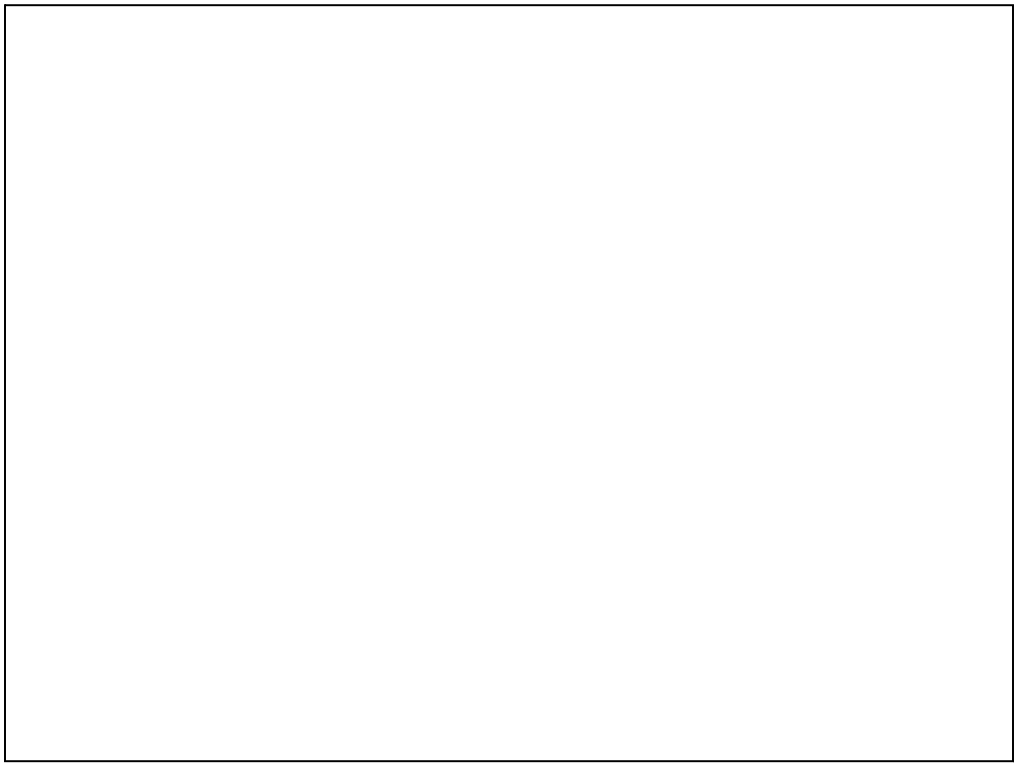


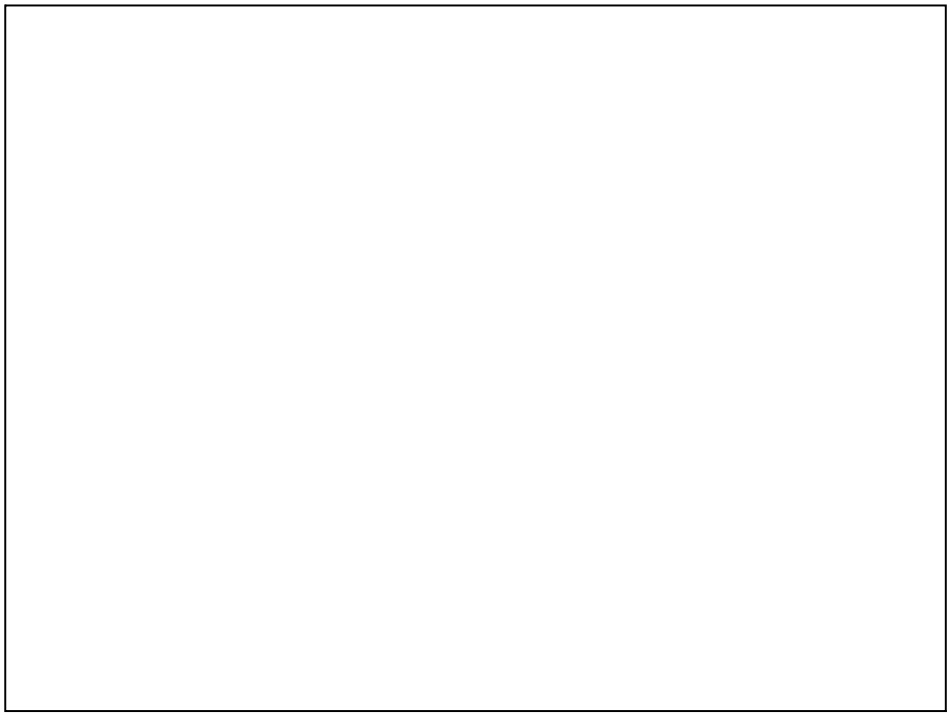


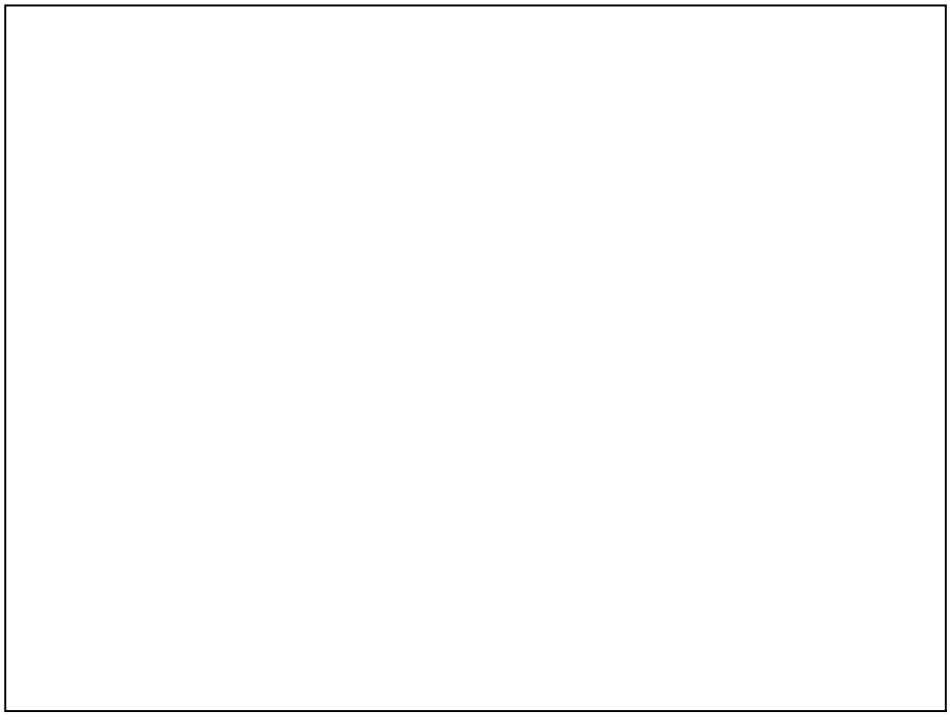


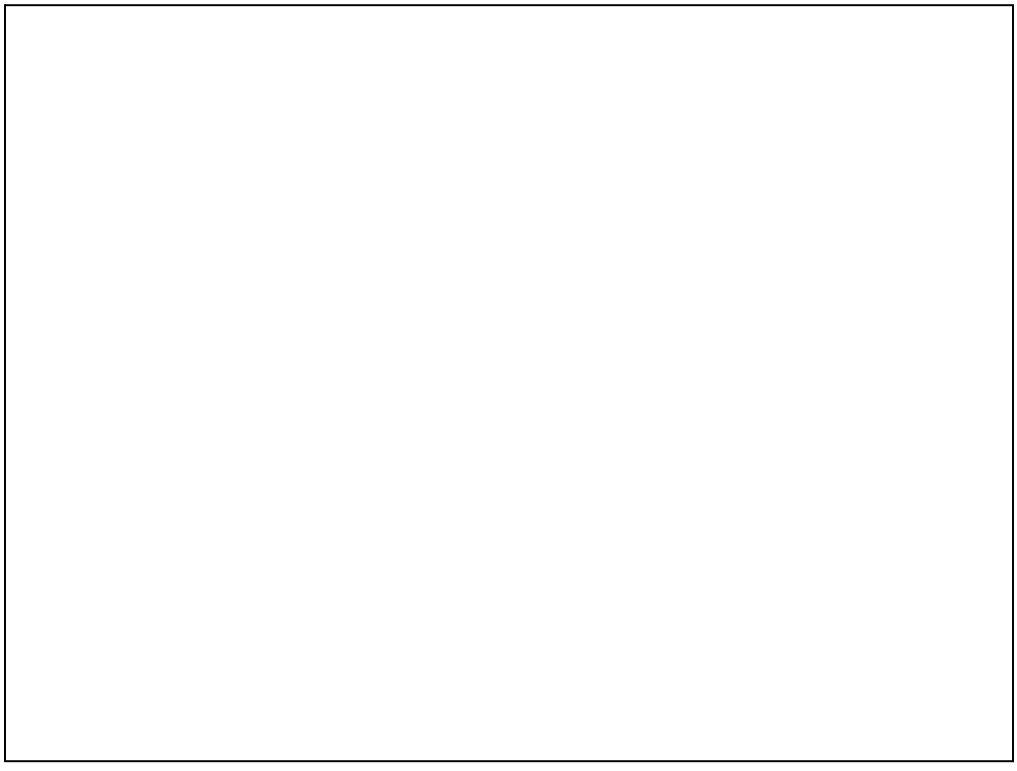


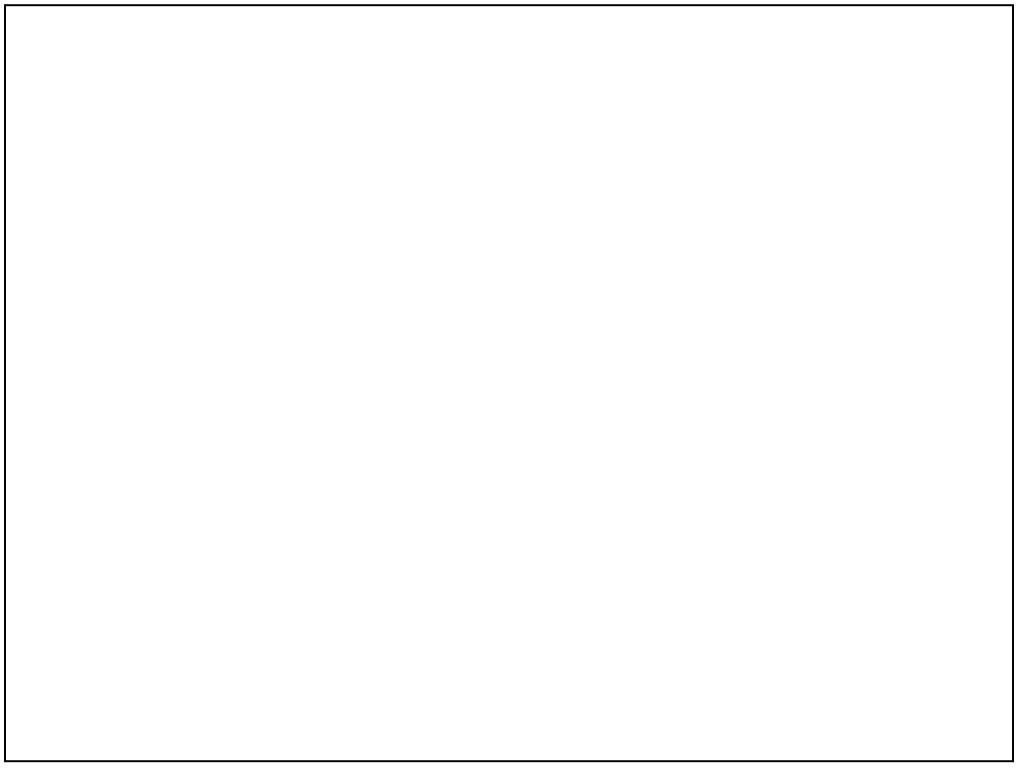


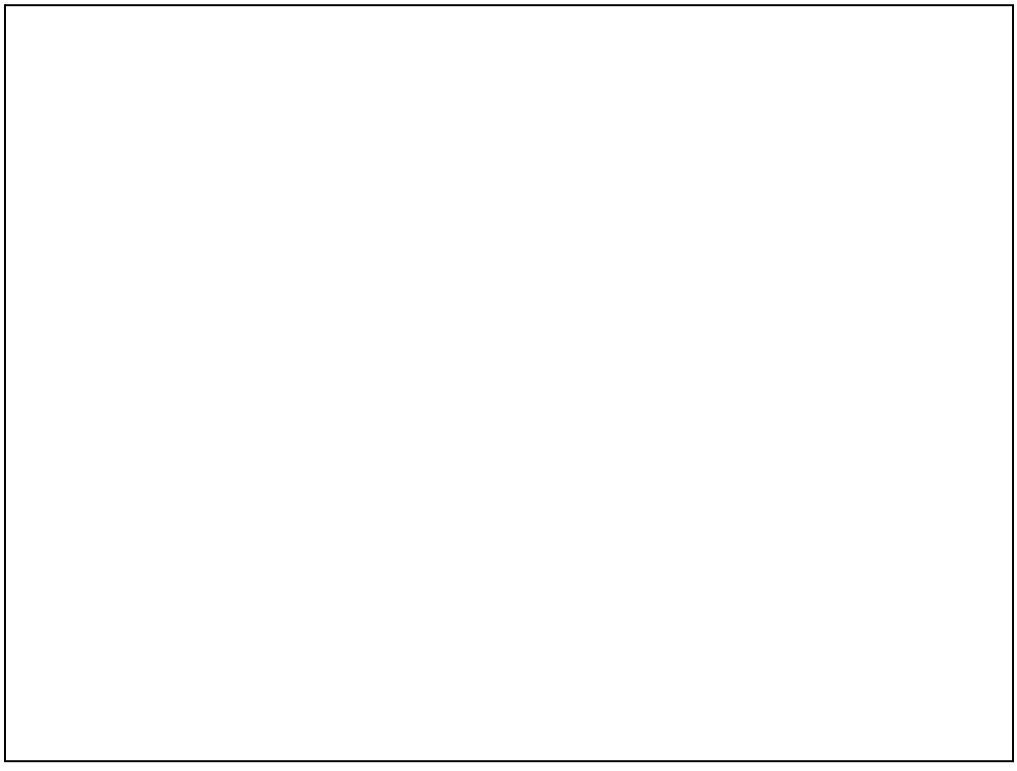


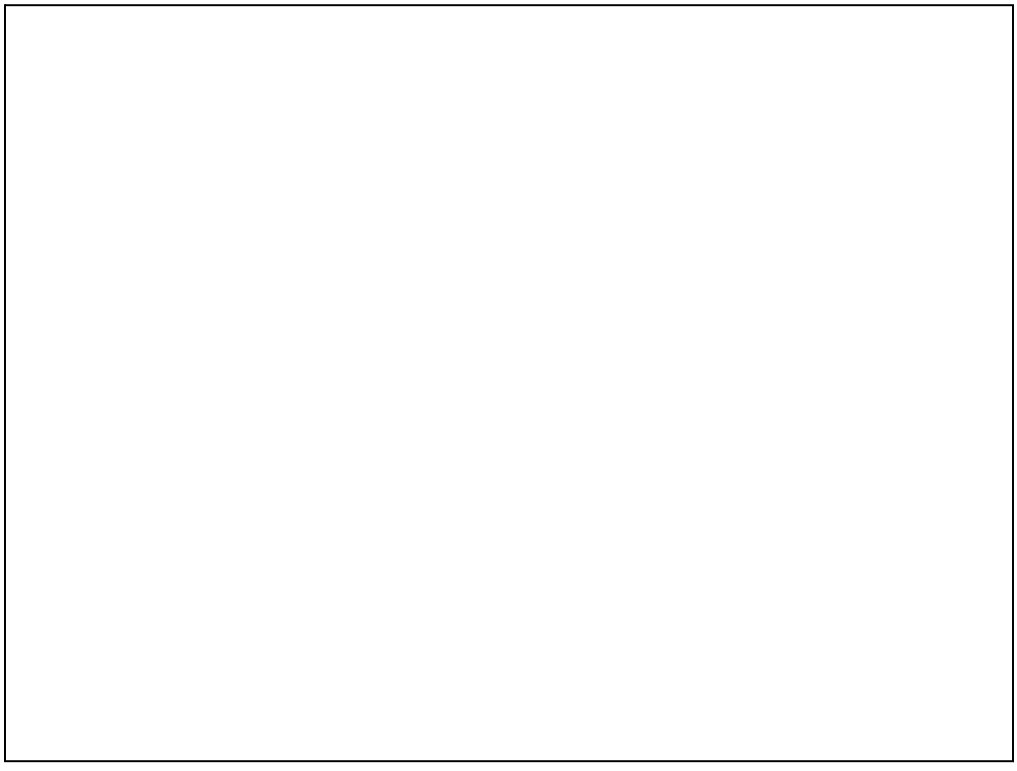


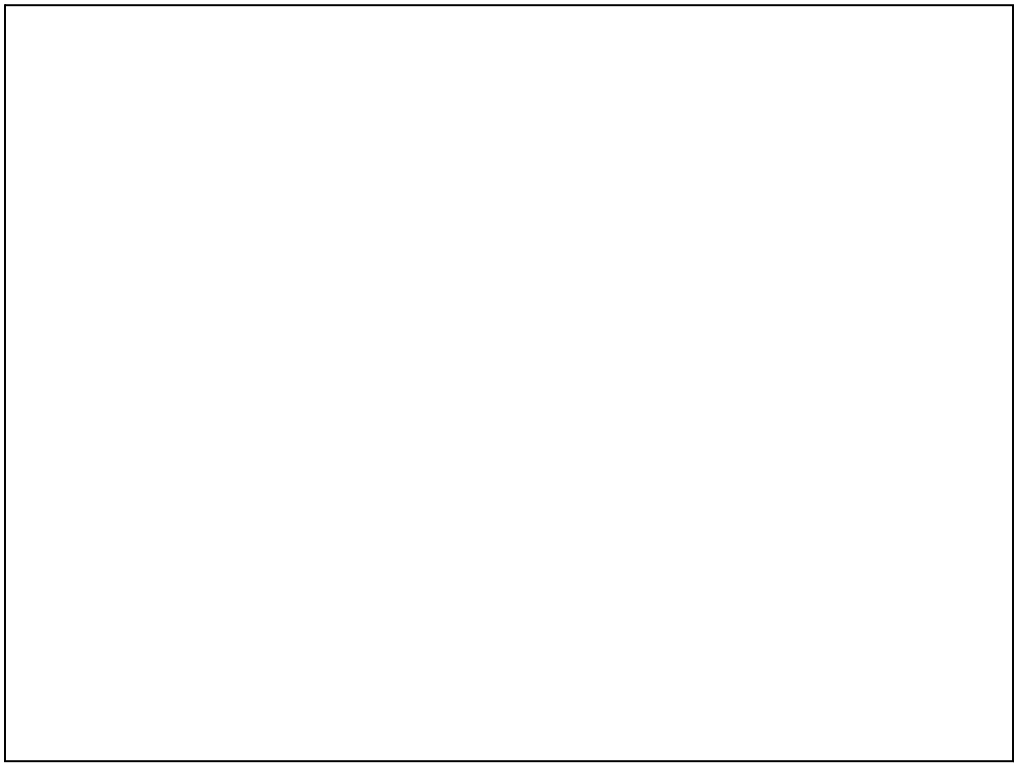


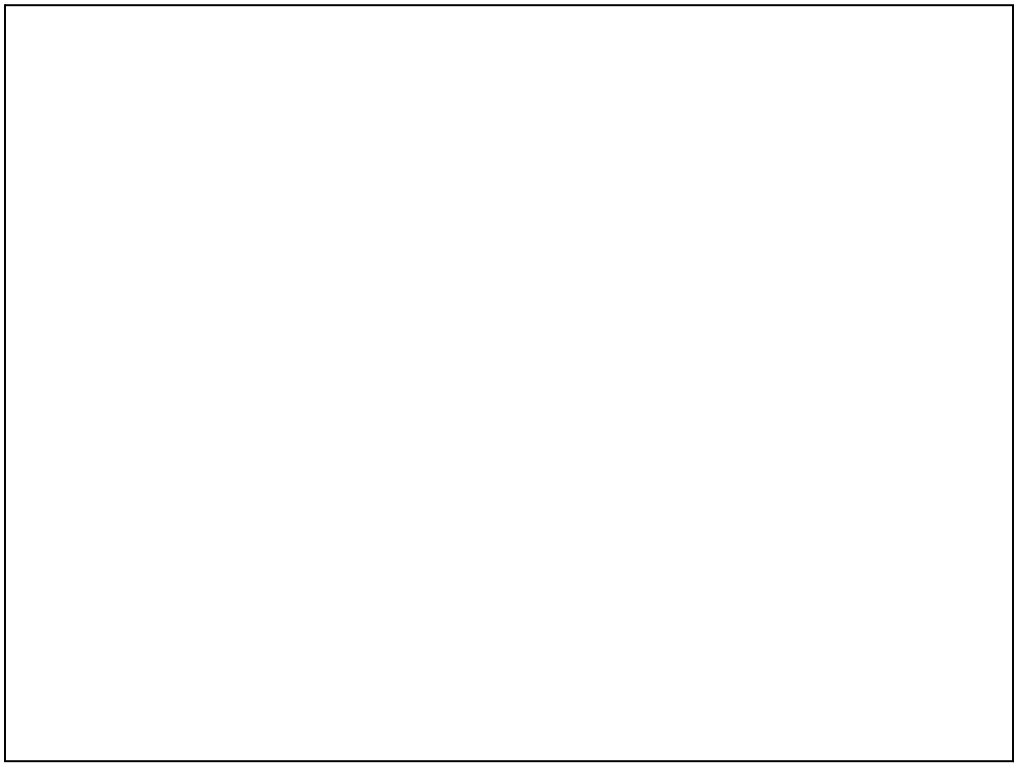






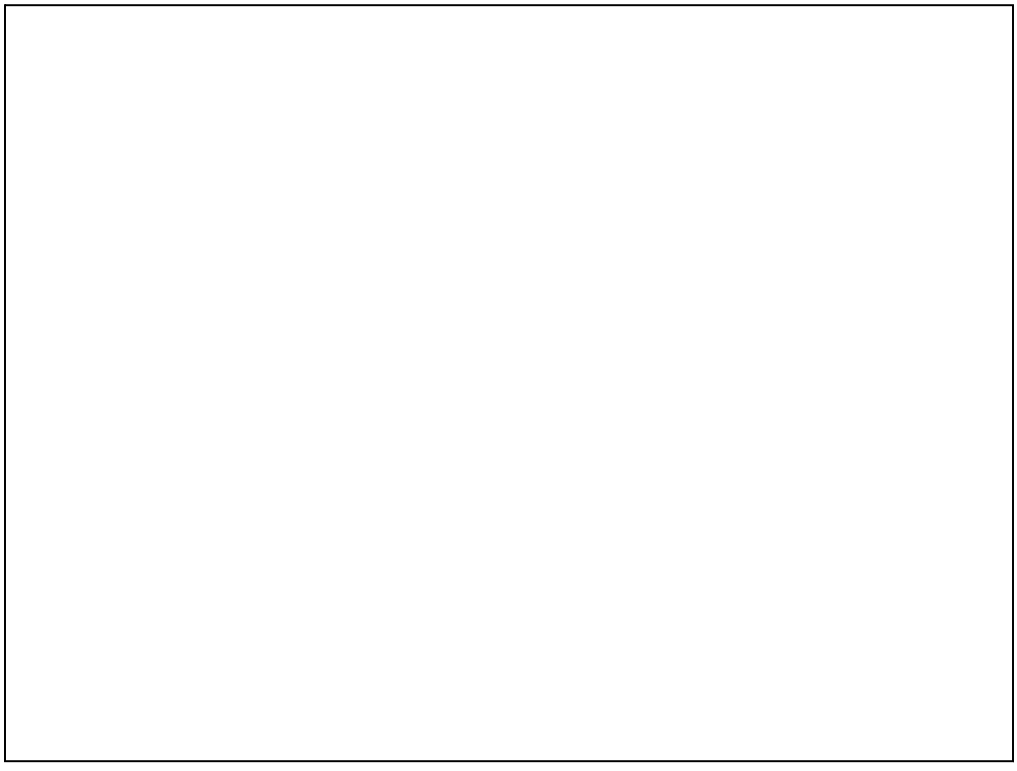






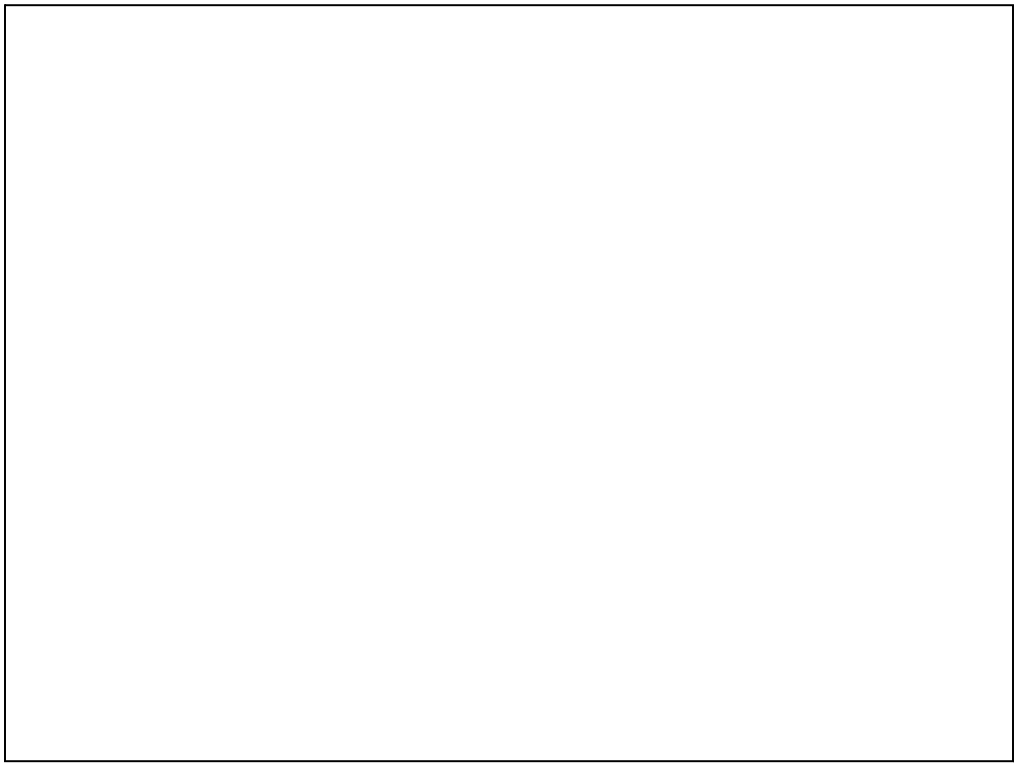
Client Side Character Converter

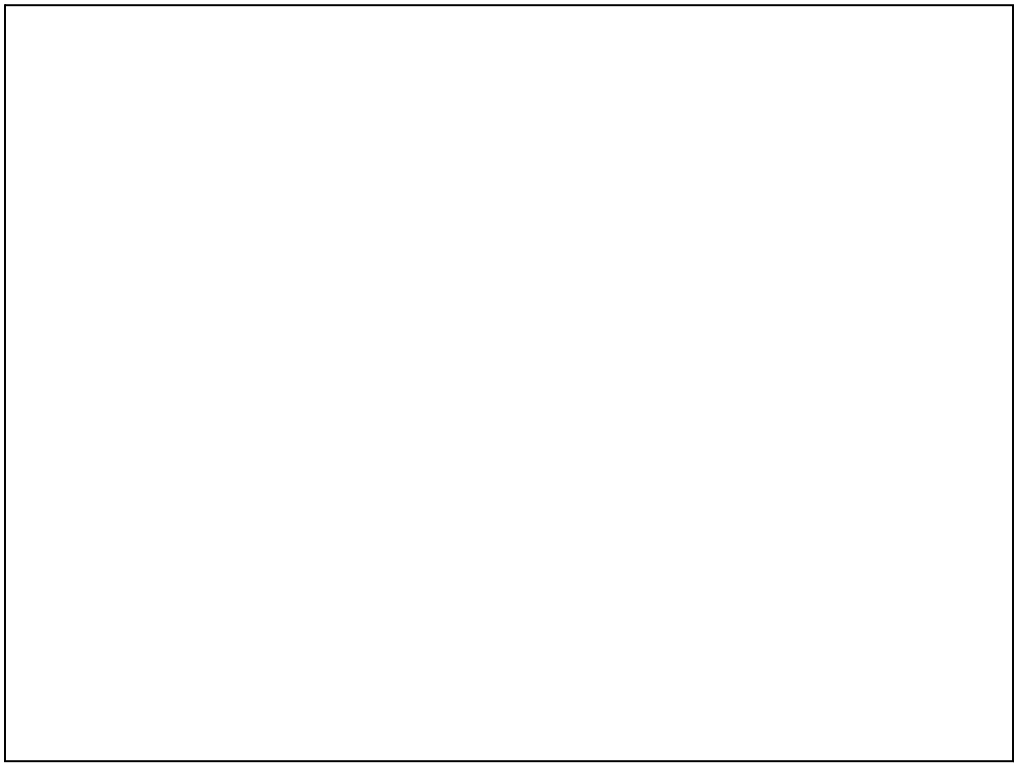
- First, we will look at code for the Client side of the Upper Case Converter …..
- Next slide define some Java Socket characteristics client side

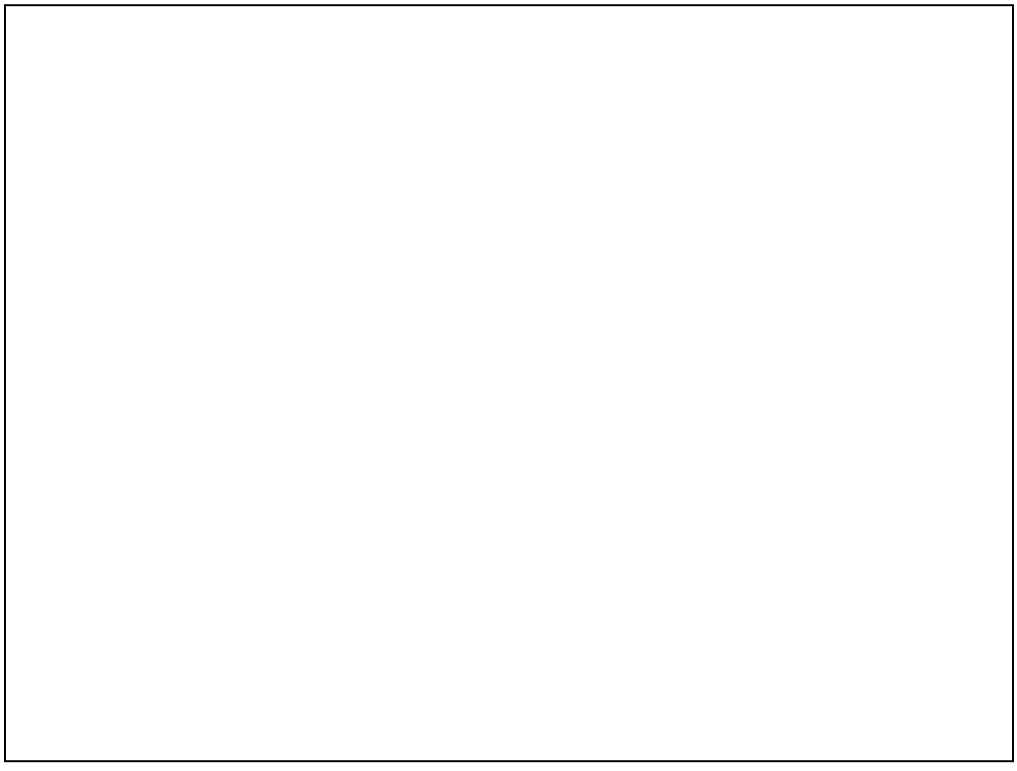


Client Uppercase Converter

- **Code Logic**
  - Accept a string to be converted from the keyboard
  - Attach to a Uppercase Server via socket
  - Send the string through the socket
  - Read the string back from the socket
  - Print the string to the terminal
  - Close the connection

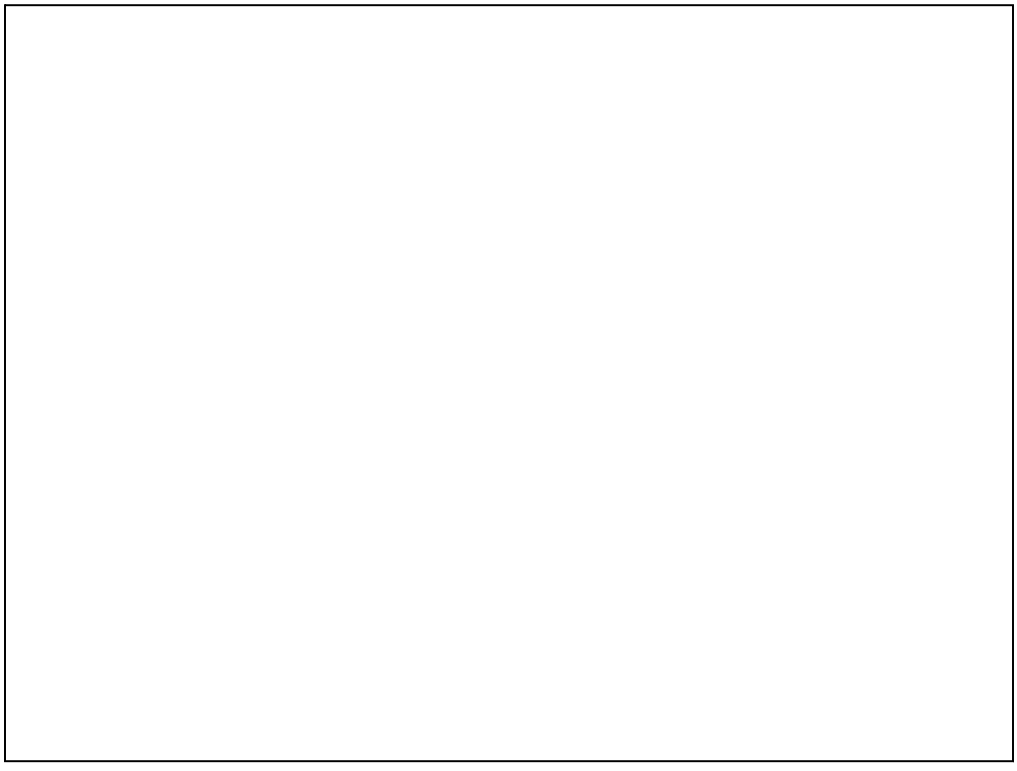


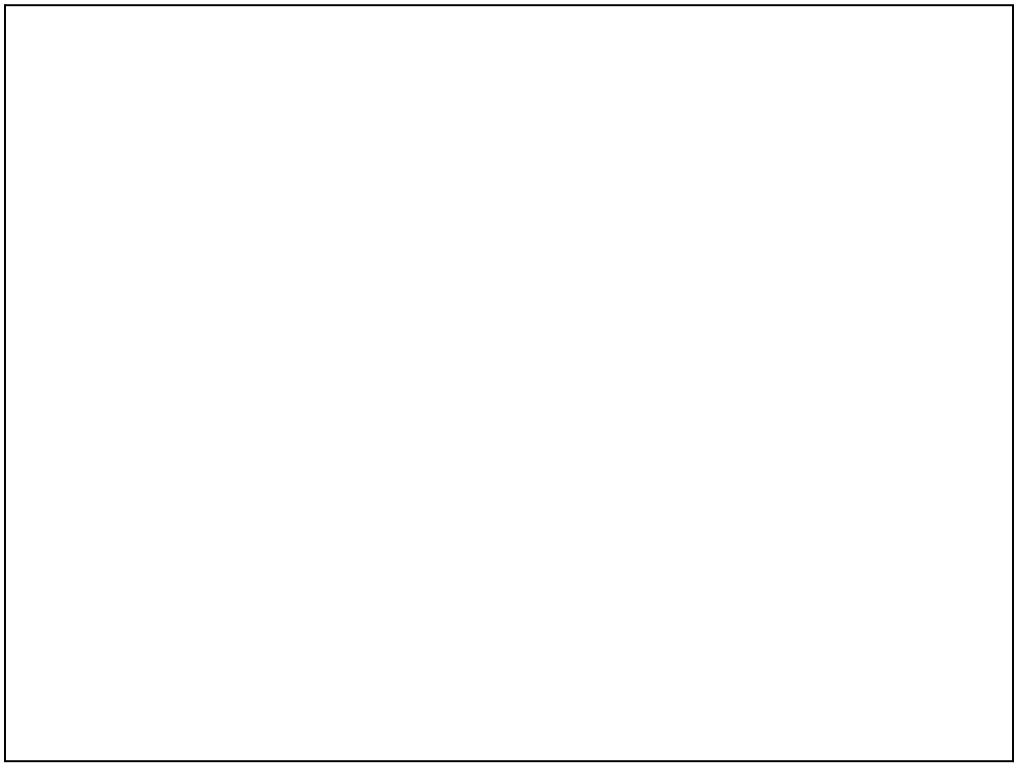


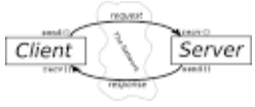


Server Uppercase Converter

- **Code Logic**
  - Set up a ServerSocket
  - Listen for a client on the ServerSocket and spawn a new socket for the client
  - Attach input and output streams to new socket
  - Read the string from the socket and convert it to uppercase
  - Send it the uppercase string through the socket
  - Close the connection to the new socket
  - Return to listening for a new client







Running the Client/Sever