

# CS 213 Winter 2022

## Bomb Lab: Understanding Machine-level Programs

### 1 Introduction

The nefarious *Dr. Evil* has planted a slew of “binary bombs” on our class machines. A binary bomb is a program that consists of a sequence of phases. Each phase expects you to type a particular string on `stdin`. If you type the correct string, then the phase is *defused* and the bomb proceeds to the next phase. Otherwise, the bomb *explodes* by printing “BOOM!!!” and then terminating. The bomb is defused when every phase has been defused.

There are too many bombs for us to deal with, so we are giving each student a bomb to defuse. Your mission, which you have no choice but to accept, is to defuse your bomb before the due date. Good luck, and welcome to the bomb squad!

### Step 1: Get Your Bomb

You can obtain your bomb by pointing your web browser at:

```
http://moore.wot.eecs.northwestern.edu:15213/
```

Be patient. This website might take 20 seconds to load. After it does, it will display a binary bomb request form for you to fill in. Enter the NetID and email address of you and your partner (or just the first NetID if you are working independently) and hit the Submit button. The server will build your bomb and return it to your browser in a `tar` file called `bombk.tar`, where  $k$  is the unique number of your bomb.

After you download that file, you’ll need to upload it to the EECS server so you can work on it. You can do so with the ‘`scp`’ command. It copies files between computers. The following command will copy the file from your own computer into your home directory on Moore (replace `bombk` with the filename for your bomb and `netid` with your NetID). You MUST run the command on your own computer inside the directory which has your `bombk.tar`. It should work fine on MacOS or on Windows in Git Bash.

```
scp bombk.tar netid@moore.wot.eecs.northwestern.edu:~/
```

You could also use an SFTP tool, such as WinSCP or FileZilla, to upload the file to the EECS server. You’ll have to use one of these if you use PuTTY to connect from Windows.

Save the `bombk.tar` file to a (protected) directory in which you plan to do your work. Then give the command: `tar -xvf bombk.tar`. This will create a directory called `./bombk` with the following files:

- `README`: Identifies the bomb and its owners.
- `bomb`: The executable binary bomb.
- `bomb.c`: Source file with the bomb's main routine and a friendly greeting from Dr. Evil.

If for some reason you request multiple bombs, this is not a problem. Choose one bomb to work on and delete the rest.

## Step 2: Defuse Your Bomb

Your job for this lab is to defuse your bomb.

You must do the assignment on one of the EECS servers. In fact, there is a rumor that Dr. Evil really is evil, and the bomb will **always blow up** if run elsewhere. There are several other tamper-proofing devices built into the bomb as well, or so we hear. Moore, Hanlon, or any of the Batman-themed Wilkinson machines are all safe.

You can use many tools to help you defuse your bomb. Please look at the **hints** section for some tips and ideas. The best way is to use your favorite debugger to step through the disassembled binary. If you don't have favorite debugger, use `gdb`.

Each time your bomb explodes it notifies the bomblab server, and you lose 1/2 point (up to a max of 20 points) in the final score for the lab. So there are consequences to exploding the bomb. You must be careful!

The first four phases are worth 10 points each. Phases 5 and 6 are a little more difficult, so they are worth 15 points each. So the maximum score you can get is 70 points.

Although phases get progressively harder to defuse, the expertise you gain as you move from phase to phase should offset this difficulty. However, the last phase will challenge even the best students, so please don't wait until the last minute to start.

The bomb ignores blank input lines. If you run your bomb with a command line argument, for example,

```
linux> ./bomb psol.txt
```

then it will read the input lines from `psol.txt` until it reaches EOF (end of file), and then switch over to `stdin`. In a moment of weakness, Dr. Evil added this feature so you don't have to keep retyping the solutions to phases you have already defused.

To avoid accidentally detonating the bomb, you will need to learn how to single-step through the assembly code and how to set breakpoints. You will also need to learn how to inspect both the registers and the memory states. One of the nice side-effects of doing the lab is that you will get very good at using a debugger. This is a crucial skill that will pay big dividends the rest of your career.

## Handin

There is no explicit handin. The bomb will notify your instructor automatically about your progress as you work on it. You can keep track of how you are doing by looking at the class scoreboard at:

```
http://moore.wot.eecs.northwestern.edu:15213/scoreboard
```

Again, this page might take a bit to load. This web page is updated continuously to show the progress for each bomb.

If you have exploded your bomb too many times and are receiving a low score, you can always request a new bomb. Be aware that the solutions to defuse the bomb are unique to each bomb though...

## Hints (*Please read this!*)

There are many ways of defusing your bomb. You can examine it in great detail without ever running the program, and figure out exactly what it does. This is a useful technique, but it not always easy to do. You can also run it under a debugger, watch what it does step by step, and use this information to defuse it. This is probably the fastest way of defusing it.

We do make one request, *please do not use brute force!* You could write a program that will try every possible key to find the right one. But this is no good for several reasons:

- You lose 1/2 point (up to a max of 20 points) every time you guess incorrectly and the bomb explodes.
- Every time you guess wrong, a message is sent to the bomblab server. You could very quickly saturate the network with these messages, and cause the system administrators to revoke your computer access.
- We haven't told you how long the strings are, nor have we told you what characters are in them. Even if you made the (incorrect) assumptions that they all are less than 80 characters long and only contain letters, then you will have  $26^{80}$  guesses for each phase. This will take a very long time to run, and you will not get the answer before the assignment is due.

There are many tools which are designed to help you figure out both how programs work, and what is wrong when they don't work. Here is a list of some of the tools you may find useful in analyzing your bomb, and hints on how to use them.

- gdb

The GNU debugger, this is a command line debugger tool available on virtually every platform. You can trace through a program line by line, examine memory and registers, look at both the source code and assembly code (we are not giving you the source code for most of your bomb), set breakpoints, set memory watch points, and write scripts.

The CS:APP web site

<http://csapp.cs.cmu.edu/public/students.html>

has a very handy single-page `gdb` summary that you can print out and use as a reference. Here are some other tips for using `gdb`.

- To keep the bomb from blowing up every time you type in a wrong input, you'll want to learn how to set breakpoints.
- For online documentation, type "help" at the `gdb` command prompt, or type "man `gdb`", or "info `gdb`" at a Unix prompt.
- `gdb` is a command-line tool, but there are numerous higher-level user interfaces that have been built on top of it. Some of these include the TUI (built into `gdb`), the `ddd` visual debugger, development environments (Eclipse, CLion, KDevelop). Some people also like to run `gdb` under `gdb-mode` in `emacs`.

- `objdump -t`

This will print out the bomb's symbol table. The symbol table includes the names of all functions and global variables in the bomb, the names of all the functions the bomb calls, and their addresses. You may learn something by looking at the function names!

- `objdump -d`

Use this to disassemble all of the code in the bomb. You can also just look at individual functions. Reading the assembler code can tell you how the bomb works.

Although `objdump -d` gives you a lot of information, it doesn't tell you the whole story. Calls to system-level functions are displayed in a cryptic form. For example, a call to `sscanf` might appear as:

```
8048c36: e8 99 fc ff ff  call    80488d4 <_init+0x1a0>
```

To determine that the call was to `sscanf`, you would need to disassemble within `gdb`.

- `strings`

This utility will display the printable strings in your bomb.

Looking for a particular tool? How about documentation? Don't forget, the commands `apropos`, `man`, and `info` are your friends. In particular, `man ascii` might come in useful. `info gas` will give you more than you ever wanted to know about the GNU Assembler. Also, the web may also be a treasure trove of information. If you get stumped, feel free to ask your instructor for help.