Booms with Ghidra

Introduction

The Bomb Lab is a reverse engineering challenge designed to enhance understanding of low-level program behavior, assembly analysis, and debugging techniques. The objective is to analyze a compiled binary and provide correct inputs for six sequential phases, along with an optional secret phase, without triggering the explode_bomb() function.

This write-up documents the methodology, analysis techniques, and reverse-engineering logic used to successfully defuse all phases using **Ghidra.**

Tools and Resources Used

Primary Tools

- **Ghidra** – Static analysis and decompilation
- **GDB** – Dynamic debugging and runtime verification
- **objdump** – Assembly inspection (supporting tool)

Methodology

The analysis followed a structured reverse-engineering workflow:

1. **Binary loading into Ghidra**
2. **Function identification** using symbol tree
3. **Decompilation review** (C-like pseudocode)
4. **Assembly cross-verification**
5. **Logic reconstruction**
6. **Runtime validation** using GDB

Each phase was analyzed independently to avoid cascading failures.

Phase-Wise Analysis

Phase 1: String Comparison

Objective: Validate a user-provided string against a hardcoded reference string.

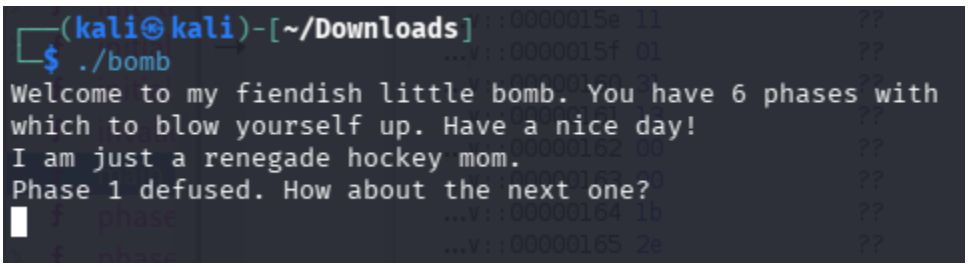
Analysis:

```
2 void phase_1(char input)
3
4 {
5   int result;
6
7   result = strings_not_equal(input,"I am just a renegade hockey mom.");
8   if (result != 0) {
9     explode_bomb();
10  }
11  return;
12 }
```

- The decompiled code revealed a call to strings_not_equal().
- A static string pointer was passed as one argument.
- If the comparison failed, execution branched to explode_bomb().

Answer:

“I am just a renegade hockey mom.”



Phase 2: Numerical Sequence Validation

Objective: Verify a sequence of six integers follows a specific mathematical rule.

Analysis:

```
void phase_2(int input)

{
  int *numPointer;
  long in_FS_OFFSET;
  int arrayofnum [6];
  long security_check;

  numPointer = arrayofnum;
  security_check = *(long *)(in_FS_OFFSET + 0x28);
  read_six_numbers(input,arrayofnum);
  if (arrayofnum[0] != 1) {
    explode_bomb();
  }
  do {
    if (numPointer[1] != *numPointer * 2) {
      explode_bomb();
    }
    numPointer = numPointer + 1;
  } while (numPointer != arrayofnum + 5);
  if (security_check == *(long *)(in_FS_OFFSET + 0x28)) {
    return;
  }
                    /* WARNING: Subroutine does not return */
  __stack_chk_fail();
}
```

- Input was read using read_six_numbers().
- A loop iteratively validated each element based on the current number is double of previous one.
- Stack offsets indicated an integer array stored locally.

Answer:

1 2 4 8 16 32

```
┌──(kali㉿kali)-[~/Downloads]
└─$ ./bomb
Welcome to my fiendish little bomb. You have 6 phases with
which to blow yourself up. Have a nice day!
I am just a renegade hockey mom.
Phase 1 defused. How about the next one?
1 2 4 8 16 32
That's number 2.  Keep going!
```

Phase 3: Switch Case via jump table

Objective: Match an index-value pair using a jump table.

Analysis:

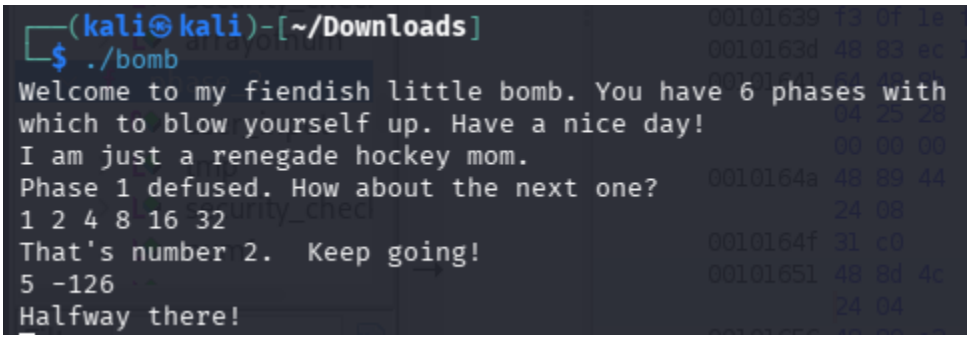
```
2 void phase_3(int user_input)
3
4 {
5   int tmp;
6   long in_FS_OFFSET;
7   int num;
8   int num1;
9   long security_check;
.0
.1   security_check = *(long *)(in_FS_OFFSET + 0x28);
.2   tmp = __isoc99_sscanf(user_input,"%d %d",&num,&num1);
.3   if (tmp < 2) {
.4     explode_bomb();
.5   }
.6   switch(num) {
.7   case 0:
.8     tmp = 0x274;
.9     break;
20   case 1:
21     tmp = 0;
22     break;
23   case 2:
24     tmp = 0;
25     goto fun1;
26   case 3:
27     tmp = 0;
28     goto fun2;
29   case 4:
30     tmp = 0;
31     goto fun3;
32   case 5:
33     tmp = 0;
34     goto fun4;
35   case 6:
36     tmp = 0;
37     goto fun5;
38   case 7:
39     tmp = 0;
40     goto fun6;
41   default:
42     explode_bomb();
43     tmp = 0;
44     goto default_fun;
45   }
```

```
46   tmp = tmp + -0x24c;
47 fun1:
48   tmp = tmp + 0x2b0;
49 fun2:
50   tmp = tmp + -0x7e;
51 fun3:
52   tmp = tmp + 0x7e;
53 fun4:
54   tmp = tmp + -0x7e;
55 fun5:
56   tmp = tmp + 0x7e;
57 fun6:
58   tmp = tmp + -0x7e;
59 default_fun:
60   if ((5 < num) || (num1 != tmp)) {
61     explode_bomb();
62   }
63   if (security_check != *(long *)(in_FS_OFFSET + 0x28)) {
64                     /* WARNING: Subroutine does not return */
65     __stack_chk_fail();
66   }
67   return;
68 }
```

- Parses **two integers** using sscanf; bomb explodes if fewer than two values are read
- First integer (num) controls a **switch statement**
- Switch uses a mix of break and goto, creating **non-linear control flow**
- Each case determines the **entry point** into an arithmetic sequence
- Arithmetic is performed through **fall-through labels**, accumulating additions and subtractions
- Final computed value depends on **where execution starts**, not just the case number
- Post-computation check restricts num to **≤ 5**
- Second integer (num1) must **exactly equal** the computed value
- Any mismatch triggers explode_bomb()
- Phase tests **control-flow tracking**, **switch lowering**, and **arithmetic reconstruction**

Answer:

5 -126



Phase 4: Recursive Function Analysis

Objective: Provide input that satisfies a recursive computation.

Analysis:

```
void phase_4(int input)

{
  int numofinput;
  undefined4 in_register_0000003c;
  long in_FS_OFFSET;
  uint first_intput;
  int second_input;
  long security_check;

  security_check = *(long *)(in_FS_OFFSET + 0x28);
  numofinput = __isoc99_sscanf(CONCAT44(in_register_0000003c,input),"%d %d",&first_intput,
                               &second_input);
  if ((numofinput != 2) || (0xe < first_intput)) {
    explode_bomb();
  }
  numofinput = func4(first_intput,0,0xe);
  if ((numofinput != 10) || (second_input != 10)) {
    explode_bomb();
  }
  if (security_check == *(long *)(in_FS_OFFSET + 0x28)) {
    return;
  }
                    /* WARNING: Subroutine does not return */
  __stack_chk_fail();
}
```

```
int func4(int num_1,int zero,int fourteen)

{
  int num;
  int numl;

  numl = (fourteen - zero) / 2 + zero;
  if (num_1 < numl) {
    num = func4(num_1,zero,numl + -1);
    numl = numl + num;
  }
  else if (numl < num_1) {
    num = func4(num_1,numl + 1,fourteen);
    numl = numl + num;
  }
  return numl;
}
```

- A recursive function (named func4) was identified.
- The logic resembled a **binary search with accumulated return values**.
- Incorrect traversal paths resulted in failure.

Answer:

3 10

```
┌──(kali㉿kali)-[~/Downloads]
└─$ ./bomb
Welcome to my fiendish little bomb. You have 6 phases with
which to blow yourself up. Have a nice day!
I am just a renegade hockey mom.
Phase 1 defused. How about the next one?
1 2 4 8 16 32
That's number 2.  Keep going!
5 -126
Halfway there!
3 10
So you got that one.  Try this one.
```

Phase 5: Character Mapping Bitwise Operations

Objective: Transform a 6-character string using a lookup table.

Analysis:

```
void phase_5(int user_input)

{
  int j;
  int i;
  long in_FS_OFFSET;
  uint num1;
  int num2;
  long security_checker;

  security_checker = *(long *)(in_FS_OFFSET + 0x28);
  j = __isoc99_sscanf(user_input,"%d %d",&num1,&num2);
  if (j < 2) {
    explode_bomb();
  }
  num1 = num1 & 0xf;
  if (num1 != 0xf) {
    j = 0;
    i = 0;
    do {
      i = i + 1;
      num1 = array.3471[(int)num1];
      j = j + num1;
    } while (num1 != 0xf);
    num1 = 0xf;
    if ((i == 0xf) && (num2 == j)) goto LAB_0010183a;
  }
  explode_bomb();
LAB_0010183a:
  if (security_checker == *(long *)(in_FS_OFFSET + 0x28)) {
    return;
  }
                    /* WARNING: Subroutine does not return */
  __stack_chk_fail();
}
```

- Parses **two integers** from user input using sscanf
- Bomb explodes if **both integers are not provided**
- First integer (num1) is **masked with 0xF** (lower 4 bits only)
- If masked value equals 0xF, the phase immediately fails
- Masked num1 is used as an **index into a fixed integer array**
- Enters a **loop that follows a chain of indices** through the array
- On each iteration:
    - The next index is read from the array
    - A running **sum (j)** is accumulated
    - A **step counter (i)** is incremented
- Loop continues until the value 0xF is reached
- After loop completion:
    - The number of steps must be **exactly 15**
    - The accumulated sum must **match the second input (num2)**
- If either condition fails, explode_bomb() is called
- Phase tests **bit masking**, **array-based traversal**, **loop control**, and **state accumulation**
- Includes a **stack canary check** to detect stack corruption

Answer:

```c
#include <stdio.h>

int main() {
    int array[16] = {
        10,  2, 14,  7,
         8, 12, 15, 11,
         0,  4,  1, 13,
         3,  9,  6,  5
    };

    int num1 = 5;
    int j = 0;
    int i = 0;

    do {
        i++;
        num1 = array[num1];
        j += num1;
    } while (num1 != 0xf);

    printf("steps: %d\n", i);
    printf("sum: %d\n", j);

    return 0;
}
```

```
┌──(kali㉿kali)-[~/Downloads]
└─$ ./bomb
Welcome to my fiendish little bomb. You have 6 phases with
which to blow yourself up. Have a nice day!
I am just a renegade hockey mom.
Phase 1 defused. How about the next one?
1 2 4 8 16 32
That's number 2.  Keep going!
5 -126
Halfway there!
3 10
So you got that one.  Try this one.
5 115
Good work!  On to the next...
```

Phase 6: Linked List Reordering

Objective: Reorder a linked list so that node values are sorted.

Analysis:

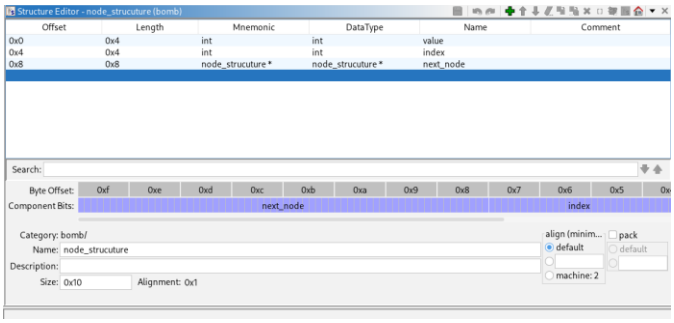
```
4 void phase_6(int input)
5
6 {
7   int i;
8   node_strucuture *current_node;
9   long j;
0   int *piVar1;
1   long index;
2   long in_FS_OFFSET;
3   int six_num [8];
4   node_strucuture node [6];
5
6   piVar1 = six_num;
7   node[3].next_node = *(node_strucuture **)(in_FS_OFFSET + 0x28);
8   read_six_numbers(input,six_num);
9   index = 1;
0   while( true ) {
1     if (5 < *piVar1 - 1U) {
2       explode_bomb();
3     }
4     j = index;
5     if (5 < (int)index) break;
6     do {
7       if (*piVar1 == six_num[j]) {
8         explode_bomb();
9       }
0       j = j + 1;
1     } while ((int)j < 6);
2     index = index + 1;
3     piVar1 = piVar1 + 1;
4   }
5   index = 0;
6   do {
7     i = 1;
8     current_node = &node1;
9     if (1 < six_num[index]) {
0       do {
1         current_node = current_node->next_node;
2         i = i + 1;
3       } while (i != six_num[index]);
4     }
5     *(node_strucuture **)(&node[0].value + index * 2) = current_node;
6     index = index + 1;
7   } while (index != 6);
8   *(node_strucuture **)(node[0]._0_8_ + 8) = node[0].next_node;
9   (node[0].next_node)->next_node = (node_strucuture *)node[1]._0_8_;
0   *(node_strucuture **)(node[1]._0_8_ + 8) = node[1].next_node;
```

```
51  (node[1].next_node)->next_node = (node_strucuture *)node[2]._0_8_;
52  *(node_strucuture **)(node[2]._0_8_ + 8) = node[2].next_node;
53  (node[2].next_node)->next_node = (node_strucuture *)0x0;
54  i = 5;
55  piVar1 = (int *)node[0]._0_8_;
56  do {
57    if (*piVar1 < **(int **)(piVar1 + 2)) {
58      explode_bomb();
59    }
60    piVar1 = *(int **)(piVar1 + 2);
61    i = i + -1;
62  } while (i != 0);
63  if (node[3].next_node != *(node_strucuture **)(in_FS_OFFSET + 0x28)) {
64                    /* WARNING: Subroutine does not return */
65    __stack_chk_fail();
66  }
67  return;
68}
```

- Reads **six integers** into an array using read_six_numbers
- Each input number is validated to ensure it is in the **range 1–6**
- Nested checks ensure **all six numbers are unique** (no duplicates allowed)
- Each input value represents a **position in a predefined linked list**
- For each number:
  - Traverses the linked list starting from node1
  - Selects the node at the specified position
  - Stores selected node pointers in a new array order
- Reconstructs a **new linked list** using the selected nodes, in input order
- Explicitly updates next_node pointers to form the new list
- Traverses the reconstructed list to verify **node values are in non-increasing (descending) order**
- If any node's value is less than the next node's value, the bomb explodes
- Phase enforces correctness through **range checking, uniqueness, pointer manipulation, and sorting logic**
- Includes a **stack canary check** to detect stack corruption

Answer:

Define a node:



```
┌──(kali㉿kali)-[~/Downloads]
└─$ ./bomb
Welcome to my fiendish little bomb. You have 6 phases with
which to blow yourself up. Have a nice day!
I am just a renegade hockey mom.
Phase 1 defused. How about the next one?
1 2 4 8 16 32
That's number 2.  Keep going!
5 -126
Halfway there!
3 10
So you got that one.  Try this one.
5 115
Good work!  On to the next...
5 4 3 1 6 2
Congratulations! You've defused the bomb!
```

Secret phase: Binary Tree Traversal

Trigger Mechanism

- Activated after defusing Phase 6 via additional input validation.

Objective: Find an integer that produces a specific traversal path in a binary search tree.

Analysis:

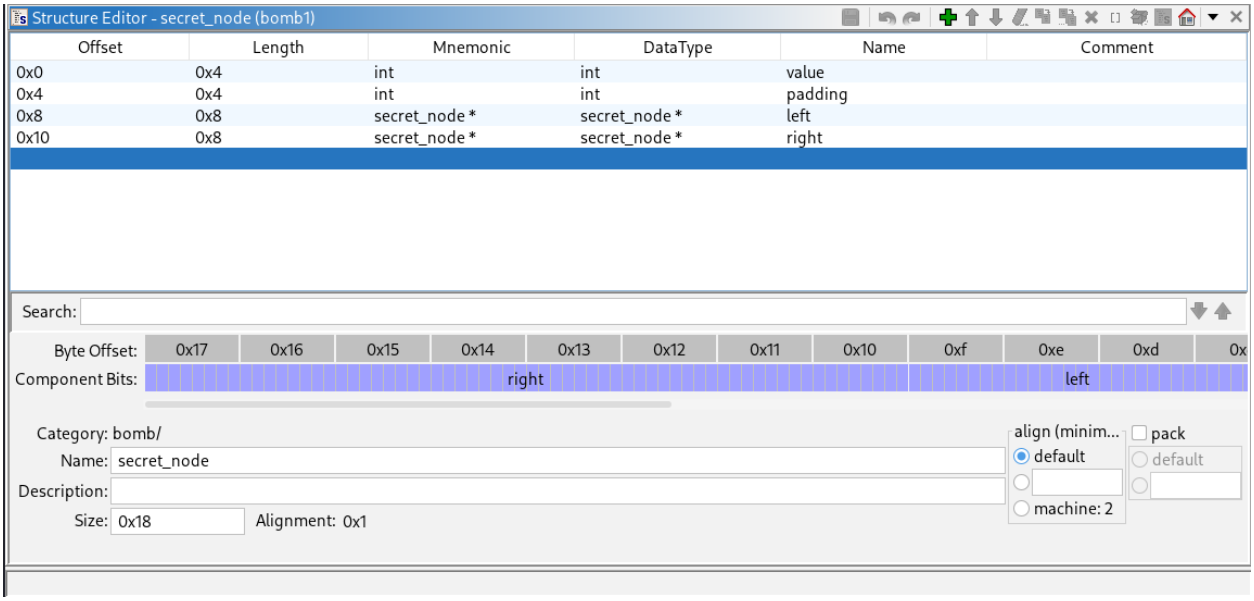
```
2 void secret_phase(void)
3
4 {
5   int return_value;
6   char *__nptr;
7   long input;
8
9   __nptr = (char *)read_line();
0   input = strtol(__nptr,(char **)0x0,10);
1   if (1000 < (int)input - 1U) {
2     explode_bomb();
3   }
4   return_value = fun7(&n1.value,(int)input);
5   if (return_value != 5) {
6     explode_bomb();
7   }
8   puts("Wow! You've defused the secret stage!");
9   phase_defused();
0   return;
1 }
2
```

```
int fun7(int *n1,int user_input)

{
  int return_value;

  if (n1 != (int *)0x0) {
    if (user_input < *n1) {
      return_value = fun7(*(int **)(n1 + 2),user_input);
      return_value = return_value * 2;
    }
    else {
      return_value = 0;
      if (*n1 != user_input) {
        return_value = fun7(*(int **)(n1 + 4),user_input);
        return_value = return_value * 2 + 1;
      }
    }
    return return_value;
  }
  return -1;
}
```

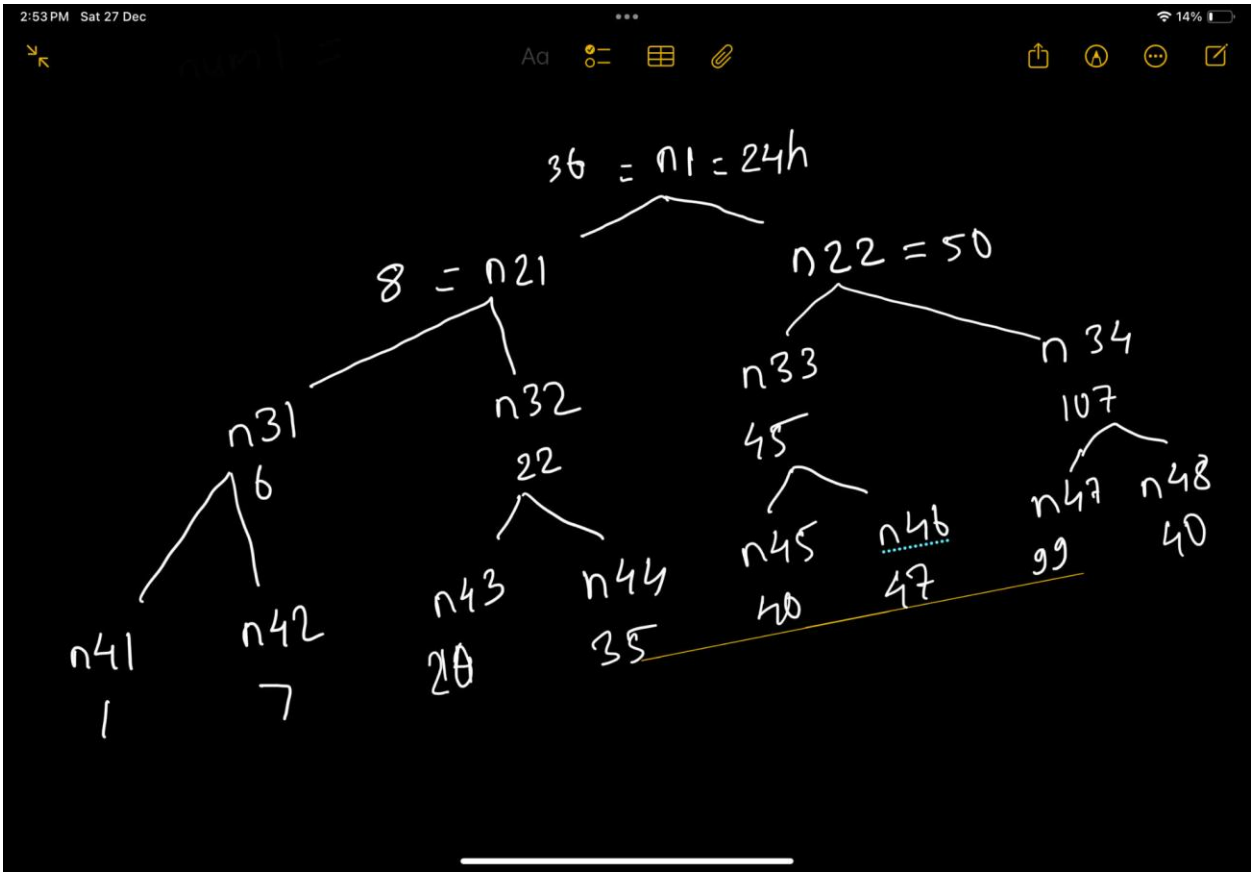
- Reads a **single line of input** from the user using read_line()
- Converts the input to an **integer** using strtol
- Validates that the input is **within a specific range** (≤ 1000)
- Calls a recursive function fun7 with the input and the root of a **binary search tree** (n1.value)
- fun7 returns a value that encodes the **path taken in the tree** (e.g., left/right traversal)
- If the return value does not equal **5**, the bomb explodes
- Successfully passing this phase prints a **congratulatory message** and calls phase_defused()
- Tests the following skills:
    - **Binary search tree traversal**
    - **Recursive function reasoning**
    - **Input validation and path encoding**
    - Understanding **recursive control flow and tree-based constraints**

Answer:

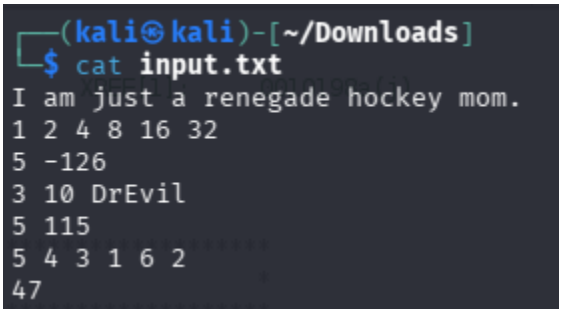
Defining the secret_node



Reconstructing Binary Tree:



Answer:


(kali㉿kali)-[~/Downloads]
$ cat input.txt
I am just a renegade hockey mom.
1 2 4 8 16 32
5 -126
3 10 DrEvil
5 115
5 4 3 1 6 2
47