2022_Spring System-Programming

Assignment #2

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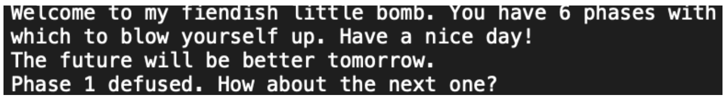
[Phase_1]

➘ Disassemble Code:

```
0000000000400e63 <phase_1>:
  400e63: 48 83 ec 08           sub    $0x8,%rsp
  400e67: be 70 22 40 00        mov    $0x402270,%esi
  400e6c: e8 21 04 00 00        callq  401292 <strings_not_equal>
  400e71: 85 c0                 test   %eax,%eax
  400e73: 75 05                 jne    400e7a <phase_1+0x17>
  400e75: 48 83 c4 08           add    $0x8,%rsp
  400e79: c3                    retq
  400e7a: e8 10 05 00 00        callq  40138f <explode_bomb>
  400e7f: eb f4                 jmp    400e75 <phase_1+0x12>
```

I explored in backward approach from the address `400e7a` that called the bomb-destructing function, expode_bomb. `400e7a` is called by `400e73`. And `400e73` is the instruction `‘jne’` to jump to the corresponding address if the condition code `ZE` is `0`.
At `400e71`, change the condition code by `‘test’` instruction the return value of `strings_not_equal`, `$eax (ZF = (Src1&src2)==0)`. So, it means if `%eax` is `false`, it will be jump.
At `400e67`, the value stored in the address `0x402270` of memory is stored in `%esi` by instruction `‘mov’`.
To sum it up, `phase_1` is a function that if input is not same with the value stored at the address `0x402270`, it will explode bomb. The value stored in `0x402270` could be confirmed using the command '`x/s 0x402270`', and the result was 'The future will be better tomorrow'.



```
Welcome to my fiendish little bomb. You have 6 phases with
which to blow yourself up. Have a nice day!
The future will be better tomorrow.
Phase 1 defused. How about the next one?
```

➜ So, the input to dismantle this bomb is **`'The future will be better tomorrow.'`**

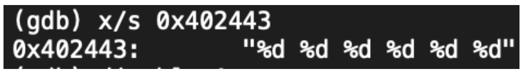
[Phase_2]

➘ Disassemble Code:

```
0000000000400e81 <phase_2>:
  400e81: 53                    push   %rbx
  400e82: 48 83 ec 20           sub    $0x20,%rsp
  400e86: 48 89 e6              mov    %rsp,%rsi
  400e89: e8 23 05 00 00        callq  4013b1 <read_six_numbers>
  400e8e: 83 3c 24 00           cmpl   $0x0,(%rsp)
  400e92: 78 07                 js     400e9b <phase_2+0x1a>
  400e94: bb 01 00 00 00        mov    $0x1,%ebx
  400e99: eb 11                 jmp    400eac <phase_2+0x2b>
  400e9b: e8 ef 04 00 00        callq  40138f <explode_bomb>
  400ea0: eb f2                 jmp    400e94 <phase_2+0x13>
  400ea2: 48 83 c3 01           add    $0x1,%rbx
  400ea6: 48 83 fb 06           cmp    $0x6,%rbx
  400eaa: 74 12                 je     400ebe <phase_2+0x3d>
  400eac: 89 d8                 mov    %ebx,%eax
  400eae: 03 44 9c fc           add    -0x4(%rsp,%rbx,4),%eax
  400eb2: 39 04 9c              cmp    %eax,(%rsp,%rbx,4)
  400eb5: 74 eb                 je     400ea2 <phase_2+0x21>
  400eb7: e8 d3 04 00 00        callq  40138f <explode_bomb>
  400ebc: eb e4                 jmp    400ea2 <phase_2+0x21>
  400ebe: 48 83 c4 20           add    $0x20,%rsp
  400ec2: 5b                    pop    %rbx
  400ec3: c3                    retq
```

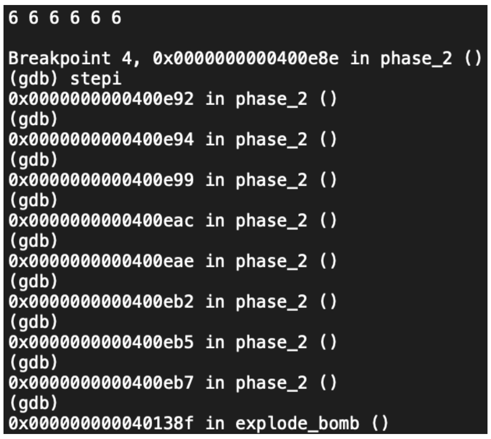
```
00000000004013b1 <read_six_numbers>:
  4013b1: 48 83 ec 08           sub    $0x8,%rsp
  4013b5: 48 89 f2              mov    %rsi,%rdx
  4013b8: 48 8d 4e 04           lea    0x4(%rsi),%rcx
  4013bc: 48 8d 46 14           lea    0x14(%rsi),%rax
  4013c0: 50                    push   %rax
  4013c1: 48 8d 46 10           lea    0x10(%rsi),%rax
  4013c5: 50                    push   %rax
  4013c6: 4c 8d 4e 0c           lea    0xc(%rsi),%r9
  4013ca: 4c 8d 46 08           lea    0x8(%rsi),%r8
  4013ce: be 43 24 40 00        mov    $0x402443,%esi
  4013d3: b8 00 00 00 00        mov    $0x0,%eax
  4013d8: e8 e3 f7 ff ff        callq  400bc0 <__isoc99_sscanf@plt>
  4013dd: 48 83 c4 10           add    $0x10,%rsp
  4013e1: 83 f8 05              cmp    $0x5,%eax
  4013e4: 7e 05                 jle    4013eb <read_six_numbers+0x3a>
  4013e6: 48 83 c4 08           add    $0x8,%rsp
  4013ea: c3                    retq
  4013eb: e8 9f ff ff ff        callq  40138f <explode_bomb>
```

Set breakpoint at `phase_2` and disassembled. In `phase_2`, there were exist two instructions to call `expode_bomb`, and there was also exist instructions to call `read_six_number`. So, I guess it's get 6 numbers as input.



```
(gdb) x/s 0x402443
0x402443:       "%d %d %d %d %d %d"
```

To confirm this, I used the command '`x/s 0x402443`' to check the string stored in `0x402443` and found that `'%d %d %d %d %d'`. So, my guess is correct that it would be the function that receives six integers as input.



```
6 6 6 6 6 6

Breakpoint 4, 0x0000000000400e8e in phase_2 ()
(gdb) stepi
0x0000000000400e92 in phase_2 ()
(gdb)
0x0000000000400e94 in phase_2 ()
(gdb)
0x0000000000400e99 in phase_2 ()
(gdb)
0x0000000000400eac in phase_2 ()
(gdb)
0x0000000000400eae in phase_2 ()
(gdb)
0x0000000000400eb2 in phase_2 ()
(gdb)
0x0000000000400eb5 in phase_2 ()
(gdb)
0x0000000000400eb7 in phase_2 ()
(gdb)
0x000000000040138f in explode_bomb ()
```

Set breakpoint at `0x400e8` where the address that sorted command immediately after the `read_six_number` call. And I entered `'6 6 6 6 6'`, and I tried to execute the instruction one by one using `'stepi'` command. Then, I found second bomb(`400ebc`) was occurred.

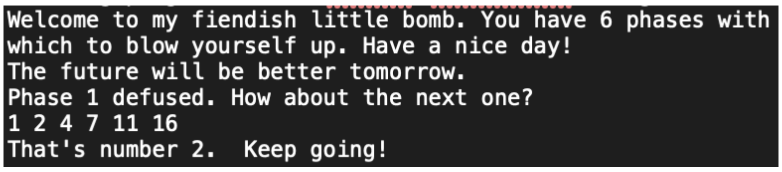
The results of the analysis of the two bombs in `phase_2` are as follows

1. at `400e9b`
By `400e92` it moves to a `400e9b` that calls `expode_bomb`.
The `'js'` is an instruction that if condition code `SF` is `1` it would be jump to the corresponding address. In other words, if it is negative, it jumps.
The `'cmpl'` at `400e8e` is an instruction that changes the condition `(SF = (src1 – src2) < 0)`
➜ If `($0x0 – (%rsp)) < 0`, it will be jump

2. at `400eb7`
If you do not jump from `400eb5`, `400eb7` will be executed, which calls the bomb. The `'je'` at `400eb5` is an instruction that if condition code `ZF` is `1` it would be jump to the corresponding address. The 'cmp' at 400eb2 is an instruction that changes the condition code `(ZF = (src1==src2))`

➜ If %eax == (%rsp, %rbx, 4), it wil be jump.

So, %eax must be same with `(%rsp, %rbx, 4)`.
Let input array is `a[6]`. Then it means input array `a[]` must be satisfy that
: `a[i] + i == a[i+1]` (when `i: 0 ~ 4`)



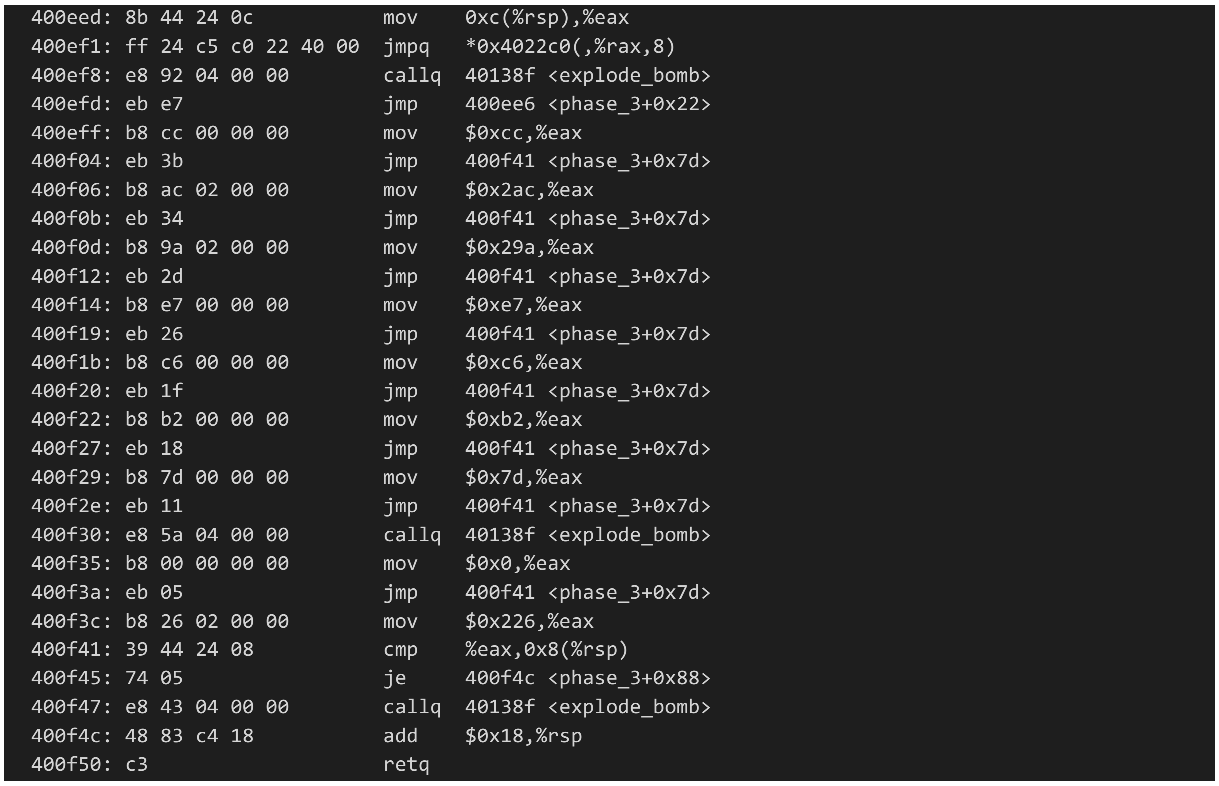
```
Welcome to my fiendish little bomb. You have 6 phases with
which to blow yourself up. Have a nice day!
The future will be better tomorrow.
Phase 1 defused. How about the next one?
1 2 4 7 11 16
That's number 2.  Keep going!
```

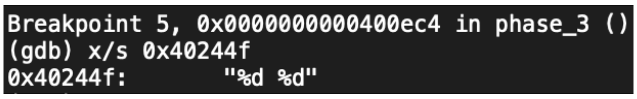
➜ So the input to dismantle this bomb is **`'1 2 4 7 11 16'`**

[Phase_3]

➘ Disassemble Code:

```
0000000000400ec4 <phase_3>:
  400ec4: 48 83 ec 18          sub    $0x18,%rsp
  400ec8: 48 8d 4c 24 08       lea    0x8(%rsp),%rcx
  400ecd: 48 8d 54 24 0c       lea    0xc(%rsp),%rdx
  400ed2: be 4f 24 40 00       mov    $0x40244f,%esi
  400ed7: b8 00 00 00 00       mov    $0x0,%eax
  400edc: e8 df fc ff ff       callq  400bc0 <__isoc99_sscanf@plt>
  400ee1: 83 f8 01             cmp    $0x1,%eax
  400ee4: 7e 12                jle    400ef8 <phase_3+0x34>
  400ee6: 83 7c 24 0c 07       cmpl   $0x7,0xc(%rsp)
  400eeb: 77 43                ja     400f30 <phase_3+0x6c>
```

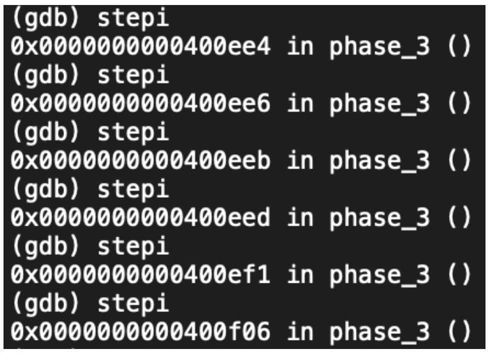

```
  400eed: 8b 44 24 0c           mov    0xc(%rsp),%eax
  400ef1: ff 24 c5 c0 22 40 00  jmpq   *0x4022c0(,%rax,8)
  400ef8: e8 92 04 00 00        callq  40138f <explode_bomb>
  400efd: eb e7                 jmp    400ee6 <phase_3+0x22>
  400eff: b8 cc 00 00 00        mov    $0xcc,%eax
  400f04: eb 3b                 jmp    400f41 <phase_3+0x7d>
  400f06: b8 ac 02 00 00        mov    $0x2ac,%eax
  400f0b: eb 34                 jmp    400f41 <phase_3+0x7d>
  400f0d: b8 9a 02 00 00        mov    $0x29a,%eax
  400f12: eb 2d                 jmp    400f41 <phase_3+0x7d>
  400f14: b8 e7 00 00 00        mov    $0xe7,%eax
  400f19: eb 26                 jmp    400f41 <phase_3+0x7d>
  400f1b: b8 c6 00 00 00        mov    $0xc6,%eax
  400f20: eb 1f                 jmp    400f41 <phase_3+0x7d>
  400f22: b8 b2 00 00 00        mov    $0xb2,%eax
  400f27: eb 18                 jmp    400f41 <phase_3+0x7d>
  400f29: b8 7d 00 00 00        mov    $0x7d,%eax
  400f2e: eb 11                 jmp    400f41 <phase_3+0x7d>
  400f30: e8 5a 04 00 00        callq  40138f <explode_bomb>
  400f35: b8 00 00 00 00        mov    $0x0,%eax
  400f3a: eb 05                 jmp    400f41 <phase_3+0x7d>
  400f3c: b8 26 02 00 00        mov    $0x226,%eax
  400f41: 39 44 24 08           cmp    %eax,0x8(%rsp)
  400f45: 74 05                 je     400f4c <phase_3+0x88>
  400f47: e8 43 04 00 00        callq  40138f <explode_bomb>
  400f4c: 48 83 c4 18           add    $0x18,%rsp
  400f50: c3                    retq
```


```
Breakpoint 5, 0x0000000000400ec4 in phase_3 ()
(gdb) x/s 0x40244f
0x40244f:       "%d %d"
```

Set breakpoint at phase_3. Likewise phase_2, I used the command ‘x/s 0x40244f’ to check the string stored in 0x40244f and found that '%d %d'. In fact, we can infer by instructions of 400ec8 & 400ecd without using the above command. The first argument is stored at 0xc(%rsp), and the second argument is at 0x8(%rsp).

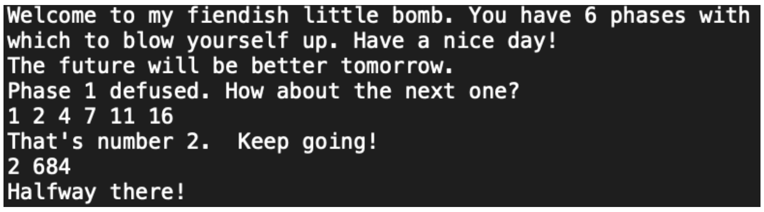
The ‘cmp’ and ‘jle’ instructions at 400ee1 and 400ee4, it means if %eax is less than or equal to $0x1, jump to the corresponding address that calls expode_bomb. **So, if number of input is less than or equal to 1, it explodes!**

The ‘cmpl’ and ‘ja’ instructions at 400ee6 and 400eeb, it means if 0xc(%rsp) (first arguments) is greater than 0x7, jump to the to the corresponding address(400f30) that calls expode_bomb. **So, first arguments should be less than or equal to 7.**


```
(gdb) stepi
0x0000000000400ee4 in phase_3 ()
(gdb) stepi
0x0000000000400ee6 in phase_3 ()
(gdb) stepi
0x0000000000400eeb in phase_3 ()
(gdb) stepi
0x0000000000400eed in phase_3 ()
(gdb) stepi
0x0000000000400ef1 in phase_3 ()
(gdb) stepi
0x0000000000400f06 in phase_3 ()
```

The `‘mov’` instruction at `400eed`, the value of first arguments is stored at `%eax`. And it jump to `*0x4022c0(,%rax,8)`. But I don’t know what is stored at this address. So, And I entered `‘2 3’`, and I tried to execute the instruction one by one using `‘stepi’` command. Before this. I found it jump to `0x400f06`.

The `‘mov’` instruction at `400f06`, `0x2ac = 684` is stored at `%eax`. Before executing `400f0b`, it jump to `400f41`. The `‘cmp’` and `‘je’` instructions at `400f41` and `400f45`, it means if `0x8(%rsp)` (second arguments) is equal to `%eax (==684)`, jump to the corresponding address (`400f4c`) that avoid calls expode_bomb. **So, it must be same.**



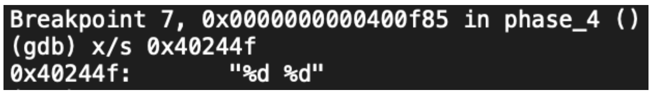
```
Welcome to my fiendish little bomb. You have 6 phases with
which to blow yourself up. Have a nice day!
The future will be better tomorrow.
Phase 1 defused. How about the next one?
1 2 4 7 11 16
That's number 2.  Keep going!
2 684
Halfway there!
```

➜ So the input to dismantle this bomb is **‘2 684’**

[Phase_4]

➘ Disassemble Code:

```
0000000000400f85 <phase_4>:
  400f85: 48 83 ec 18          sub    $0x18,%rsp
  400f89: 48 8d 4c 24 08       lea    0x8(%rsp),%rcx
  400f8e: 48 8d 54 24 0c       lea    0xc(%rsp),%rdx
  400f93: be 4f 24 40 00       mov    $0x40244f,%esi
  400f98: b8 00 00 00 00       mov    $0x0,%eax
  400f9d: e8 1e fc ff ff       callq  400bc0 <__isoc99_sscanf@plt>
  400fa2: 83 f8 02             cmp    $0x2,%eax
  400fa5: 75 07                jne    400fae <phase_4+0x29>
  400fa7: 83 7c 24 0c 0e       cmpl   $0xe,0xc(%rsp)
  400fac: 76 05                jbe    400fb3 <phase_4+0x2e>
  400fae: e8 dc 03 00 00       callq  40138f <explode_bomb>
  400fb3: ba 0e 00 00 00       mov    $0xe,%edx
  400fb8: be 00 00 00 00       mov    $0x0,%esi
  400fbd: 8b 7c 24 0c          mov    0xc(%rsp),%edi
  400fc1: e8 8b ff ff ff       callq  400f51 <func4>
  400fc6: 83 f8 1b             cmp    $0x1b,%eax
  400fc9: 75 07                jne    400fd2 <phase_4+0x4d>
  400fcb: 83 7c 24 08 1b       cmpl   $0x1b,0x8(%rsp)
  400fd0: 74 05                je     400fd7 <phase_4+0x52>
  400fd2: e8 b8 03 00 00       callq  40138f <explode_bomb>
  400fd7: 48 83 c4 18          add    $0x18,%rsp
  400fdb: c3                   retq
```



```
Breakpoint 7, 0x0000000000400f85 in phase_4 ()
(gdb) x/s 0x40244f
0x40244f:       "%d %d"
```

Set breakpoint at `phase_4`. I used the command `‘x/s 0x40244f’` to check the string stored in `0x40244f` and found that `'%d %d'`. The first argument is stored at `0xc(%rsp)`, and the second argument is at `0x8(%rsp)`.

The `‘cmp’` and `‘jne’` instructions at `400fa2` and `400fa5`, it means if `%eax` is not equal to `$0x2`, jump to the corresponding address that calls expode_bomb. **So, if number of inputs is not equal to 2, it explodes!**

The `‘cmpl’` and `‘jbe’` instructions at `400fa7` and `400fac`, it means if `0xc(%rsp)` (first arguments) is less than or equal to `$0xe(==14)`, jump to the corresponding address (`400fb3`) that avoid calls expode_bomb. **So, if first argument is greater than 14, it explodes!**

And it stored 14 at `%edx`, stored 0 at `%esi`, stored first argument's value at `%edi`.
Then call function `‘func4’`, and compare return value with `0x1b`. The `‘cmp’` and `‘jne’` instructions at `400fc6` and `400fc9`, it means if `%eax` (return value of `‘func4’`) is not equal to `$0x1b (==27)`, jump to the corresponding address that calls expode_bomb. **So, `‘func4’`must return 27.**

The `‘cmpl’` and `‘je’` instructions at `400fcb` and `400fd0`, it means if `0x8(%rsp)` (second arguments) is equal to `$0x1b (==27)`, jump to the corresponding address (`400fd7`) that avoid calls expode_bomb. **So, if second argument is not equal to 27, it explodes!**

```
0000000000400f51 <func4>:
  400f51: 53                   push   %rbx
  400f52: 89 d0                mov    %edx,%eax                // %eax = %edx
  400f54: 29 f0                sub    %esi,%eax                // %eax = %eax - %esi
  400f56: 89 c3                mov    %eax,%ebx                // %ebx = %eax
  400f58: c1 eb 1f             shr    $0x1f,%ebx               // %ebx = %ebx >> 31 (only sign)
  400f5b: 01 c3                add    %eax,%ebx                // %ebx = %ebx + %eax
  400f5d: d1 fb                sar    %ebx                     // %ebx = %ebx >> 1 (%ebx/2)
  400f5f: 01 f3                add    %esi,%ebx                // %ebx = %ebx + %esi
  400f61: 39 fb                cmp    %edi,%ebx
  400f63: 7f 08                jg     400f6d <func4+0x1c>      // if %ebx > %edi, jump
  400f65: 39 fb                cmp    %edi,%ebx
  400f67: 7c 10                jl     400f79 <func4+0x28>      // else if %ebx < %edi , jump
  400f69: 89 d8                mov    %ebx,%eax                // else (%ebx == %edi), return
  400f6b: 5b                   pop    %rbx
  400f6c: c3                   retq                            // return %eax (== %ebx)
  400f6d: 8d 53 ff             lea    -0x1(%rbx),%edx          // %edx = (%rdx) - 1
  400f70: e8 dc ff ff ff       callq  400f51 <func4>           // recursive
  400f75: 01 c3                add    %eax,%ebx
  400f77: eb f0                jmp    400f69 <func4+0x18>      // recursive
  400f79: 8d 73 01             lea    0x1(%rbx),%esi           // %esi = (%rdx) + 1
  400f7c: e8 d0 ff ff ff       callq  400f51 <func4>
  400f81: 01 c3                add    %eax,%ebx
  400f83: eb e4                jmp    400f69 <func4+0x18>      // %ebx = %ebx + %eax
```

This is disassembled code of `‘func4’`. And I added comments to some of the lines.
Interpret each part,

✗ [~ 400f5f] :

If `%edx – %esi <0`,   `ebx = (edx + esi)/2 + 0.5`.
Else   `ebx = (edx + esi)/2`

✗ [**400f61 ~**] :

Ⅰ. If %ebx > %edi

  %edx = %rbx – 1, and call ‘func4’.

  Return (the return value of the recursive call) + %ebx

Ⅱ. else if %ebx < %edi

  %edx = %rbx + 1, and call ‘func4’.

  Return (the return value of the recursive call) + %ebx

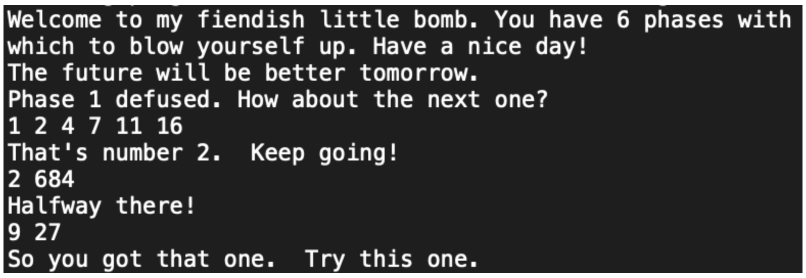
Ⅲ else (case of %ebx == %edi)

  return %ebx

To sum it up, ‘func4’ is a function that returns the sum of the visited values while binary searching to find value of %edi in the range [%edx, %esi].

To this value to be 27 (target value),

[14,0] 7 (20) ➔ [14,8] 11 (9) ➔ [10,8] 9 (0)   [range] mid (target value - mid)



```
Welcome to my fiendish little bomb. You have 6 phases with
which to blow yourself up. Have a nice day!
The future will be better tomorrow.
Phase 1 defused. How about the next one?
1 2 4 7 11 16
That's number 2.  Keep going!
2 684
Halfway there!
9 27
So you got that one.  Try this one.
```

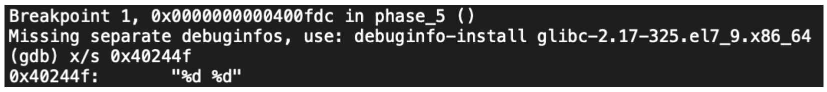
➔ So the input to dismantle this bomb is **‘9 27’**

[Phase_5]

➘ Disassemble Code:

```
0000000000400fdc <phase_5>:
  400fdc: 48 83 ec 18           sub    $0x18,%rsp
  400fe0: 48 8d 4c 24 08        lea    0x8(%rsp),%rcx
  400fe5: 48 8d 54 24 0c        lea    0xc(%rsp),%rdx
  400fea: be 4f 24 40 00        mov    $0x40244f,%esi
  400fef: b8 00 00 00 00        mov    $0x0,%eax
  400ff4: e8 c7 fb ff ff        callq  400bc0 <__isoc99_sscanf@plt>
  400ff9: 83 f8 01              cmp    $0x1,%eax
  400ffc: 7e 4a                 jle    401048 <phase_5+0x6c>
  400ffe: 8b 44 24 0c           mov    0xc(%rsp),%eax
  401002: 83 e0 0f              and    $0xf,%eax
  401005: 89 44 24 0c           mov    %eax,0xc(%rsp)
  401009: 83 f8 0f              cmp    $0xf,%eax
  40100c: 74 30                 je     40103e <phase_5+0x62>
  40100e: b9 00 00 00 00        mov    $0x0,%ecx
  401013: ba 00 00 00 00        mov    $0x0,%edx
  401018: 83 c2 01              add    $0x1,%edx
  40101b: 48 98                 cltq
  40101d: 8b 04 85 00 23 40 00  mov    0x402300(,%rax,4),%eax
```

```
 401024: 01 c1                  add    %eax,%ecx
 401026: 83 f8 0f               cmp    $0xf,%eax
 401029: 75 ed                  jne    401018 <phase_5+0x3c>
 40102b: c7 44 24 0c 0f 00 00   movl   $0xf,0xc(%rsp)
 401032: 00
 401033: 83 fa 0f               cmp    $0xf,%edx
 401036: 75 06                  jne    40103e <phase_5+0x62>
 401038: 39 4c 24 08            cmp    %ecx,0x8(%rsp)
 40103c: 74 05                  je     401043 <phase_5+0x67>
 40103e: e8 4c 03 00 00         callq  40138f <explode_bomb>
 401043: 48 83 c4 18            add    $0x18,%rsp
 401047: c3                     retq
 401048: e8 42 03 00 00         callq  40138f <explode_bomb>
 40104d: eb af                  jmp    400ffe <phase_5+0x22>
```



```
Breakpoint 1, 0x0000000000400fdc in phase_5 ()
Missing separate debuginfos, use: debuginfo-install glibc-2.17-325.el7_9.x86_64
(gdb) x/s 0x40244f
0x40244f:       "%d %d"
```

Set breakpoint at phase_5. I used the command ‘x/s 0x40244f’ to check the string stored in 0x40244f and found that '%d %d'. The first argument is stored at 0xc(%rsp), and the second argument is at 0x8(%rsp). The ‘cmp’ and ‘jle’ instructions at 400ff9 and 400ffc, it means if %eax is less than or equal to $0x1, jump to the corresponding address that calls expode_bomb.

So, if number of inputs is less than or equal to 1, it explodes!

```
 400ffe: 8b 44 24 0c            mov    0xc(%rsp),%eax
 401002: 83 e0 0f               and    $0xf,%eax
 401005: 89 44 24 0c            mov    %eax,0xc(%rsp)
 401009: 83 f8 0f               cmp    $0xf,%eax
 40100c: 74 30                  je     40103e <phase_5+0x62>
```

Store first argument at %eax, and perform ‘and’ operation with 0xf(= 15 = 1111_2). Then only the least 4 bits are left, and it is the same as the remainder when divided by 16. And restore it at 0xc(%rsp) that address of first argument. Compare %eax with 0xf(= 15) if the values are same jump to address that calls expode_bomb.

So, if the remainder when first argument divided by 16 is equal to 15, it explodes!

```
 40100e: b9 00 00 00 00         mov    $0x0,%ecx
 401013: ba 00 00 00 00         mov    $0x0,%edx
 401018: 83 c2 01               add    $0x1,%edx
 40101b: 48 98                  cltq
 40101d: 8b 04 85 00 23 40 00   mov    0x402300(,%rax,4),%eax
 401024: 01 c1                  add    %eax,%ecx
 401026: 83 f8 0f               cmp    $0xf,%eax
 401029: 75 ed                  jne    401018 <phase_5+0x3c>
```

Stored 0x0 at %eax and %edx. And below 401018 loop statement. %edx is number of iterations.

```
do while(%eax != 15){
        %edx = %edx + 1
        sign expands %eax and stores it in %rax. (instruction ‘cltq’)
        %eax = 0x402300(,%rax,4) = 4 * (%rax) + 0x402300
        %ecx = %ecx + %eax
}
```

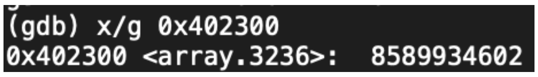
```
 40102b: c7 44 24 0c 0f 00 00   movl   $0xf,0xc(%rsp)
```

```
  401032: 00
  401033: 83 fa 0f                cmp    $0xf,%edx
  401036: 75 06                   jne    40103e <phase_5+0x62>
  401038: 39 4c 24 08             cmp    %ecx,0x8(%rsp)
  40103c: 74 05                   je     401043 <phase_5+0x67>
  40103e: e8 4c 03 00 00          callq  40138f <explode_bomb>
  401043: 48 83 c4 18             add    $0x18,%rsp
  401047: c3                      retq
```

If `%eax` is equal to `15`, so escapes the loop statement, store `15` at `0xc (%rsp)` that address first arguments stored.
Compared to `%edx` with `15`, if `%edx` is not equal to `15`, jump to address that calls `expode_bomb`.
If you avoid a bomb because `%edx` is eqaual to `15`, compare the second arguments with `%ecx` and if the two values are equal jump to the corresponding address (`401043`) that avoid calls `expode_bomb`. If else, it exploded!
So, `%edx` is equal to `15` and second argument is equal to `%ecx`.

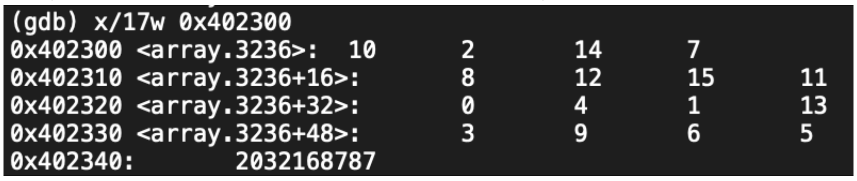
`%rsp = %rsp + 24`
Done.

What value will be stored at `0x402300` in `0x402300(,%rax,4)`?



```
(gdb) x/g 0x402300
0x402300 <array.3236>:  8589934602
```

Can confirm using the command `'x/g 0x402300'`, and the result was array. So, it is move the index as `%rax` in the array and store value of `a[%rax]` at `%eax`. I can guess that the length of the array is `16` because the remainder divided by 16 should be less than `15`.



```
(gdb) x/17w 0x402300
0x402300 <array.3236>:  10      2       14      7
0x402310 <array.3236+16>:       8       12      15      11
0x402320 <array.3236+32>:       0       4       1       13
0x402330 <array.3236+48>:       3       9       6       5
0x402340:       2032168787
```

It can confirm using the command `'x/17w 0x402300'`, (Just in case, I confirmed 17 values.)

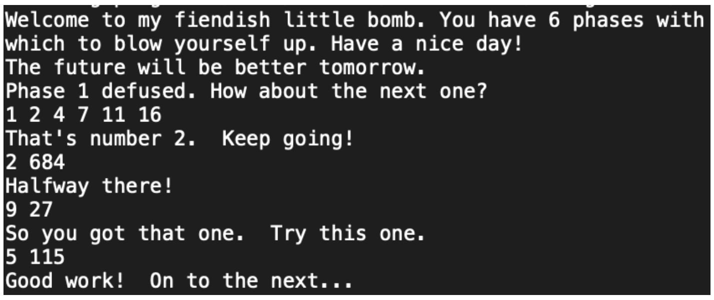
To sum it up, starting at `a[first argument]` and the value of the array positioned when moved `15` times (`15` iterations) is must be `15`. And second argument is sum of the value that stored in past array position.
Then we just decide starting index, and it can find by explore backward.

Modify given array that add index to easy find index of array.

```
0x402300 <array.3236>:          10 [0]          2 [1]           14 [2]          7 [3]
0x402310 <array.3236+16>:       8 [4]           12 [5]          15 [6]          11 [7]
0x402320 <array.3236+32>:       0 [8]           4 [9]           1 [10]          13 [11]
0x402330 <array.3236+48>:       3 [12]          9 [13]          6 [14]          5 [15]
```

```
15 [6] ➔ 6 [14] ➔ 14 [2] ➔ 2 [1] ➔ 1 [10] ➔ 10 [0] ➔ 0 [8] ➔ 8 [4] ➔ 4
[9] ➔ 9[13] ➔ 13[11] ➔ 11[7] ➔ 7[3] ➔ 3[12] ➔ 12[5]        value [index]
```

We start at 5, and sum of value is 115.



```
Welcome to my fiendish little bomb. You have 6 phases with
which to blow yourself up. Have a nice day!
The future will be better tomorrow.
Phase 1 defused. How about the next one?
1 2 4 7 11 16
That's number 2.  Keep going!
2 684
Halfway there!
9 27
So you got that one.  Try this one.
5 115
Good work!  On to the next...
```

➜ So the input to dismantle this bomb is **'`5 115`'**

[Phase_6]

➘ Disassemble Code:

```
000000000040104f <phase_6>:
  40104f: 41 56                push   %r14
  401051: 41 55                push   %r13
  401053: 41 54                push   %r12
  401055: 55                   push   %rbp
  401056: 53                   push   %rbx
  401057: 48 83 ec 50          sub    $0x50,%rsp
  40105b: 48 8d 74 24 30       lea    0x30(%rsp),%rsi
  401060: e8 4c 03 00 00       callq  4013b1 <read_six_numbers>
  401065: 4c 8d 64 24 30       lea    0x30(%rsp),%r12
  40106a: 4d 89 e5             mov    %r12,%r13
  40106d: 41 be 00 00 00 00    mov    $0x0,%r14d
  401073: eb 26                jmp    40109b <phase_6+0x4c>
  401075: e8 15 03 00 00       callq  40138f <explode_bomb>
  40107a: eb 2e                jmp    4010aa <phase_6+0x5b>
  40107c: 83 c3 01             add    $0x1,%ebx
  40107f: 83 fb 05             cmp    $0x5,%ebx
  401082: 7f 13                jg     401097 <phase_6+0x48>
  401084: 48 63 c3             movslq %ebx,%rax
  401087: 8b 44 84 30          mov    0x30(%rsp,%rax,4),%eax
  40108b: 39 45 00             cmp    %eax,0x0(%rbp)
  40108e: 75 ec                jne    40107c <phase_6+0x2d>
  401090: e8 fa 02 00 00       callq  40138f <explode_bomb>
  401095: eb e5                jmp    40107c <phase_6+0x2d>
  401097: 49 83 c5 04          add    $0x4,%r13
  40109b: 4c 89 ed             mov    %r13,%rbp
  40109e: 41 8b 45 00          mov    0x0(%r13),%eax
  4010a2: 83 e8 01             sub    $0x1,%eax
  4010a5: 83 f8 05             cmp    $0x5,%eax
  4010a8: 77 cb                ja     401075 <phase_6+0x26>
  4010aa: 41 83 c6 01          add    $0x1,%r14d
  4010ae: 41 83 fe 06          cmp    $0x6,%r14d
  4010b2: 74 05                je     4010b9 <phase_6+0x6a>
  4010b4: 44 89 f3             mov    %r14d,%ebx
  4010b7: eb cb                jmp    401084 <phase_6+0x35>
  4010b9: 49 8d 4c 24 18       lea    0x18(%r12),%rcx
  4010be: ba 07 00 00 00       mov    $0x7,%edx
  4010c3: 89 d0                mov    %edx,%eax
  4010c5: 41 2b 04 24          sub    (%r12),%eax
  4010c9: 41 89 04 24          mov    %eax,(%r12)
  4010cd: 49 83 c4 04          add    $0x4,%r12
  4010d1: 4c 39 e1             cmp    %r12,%rcx
  4010d4: 75 ed                jne    4010c3 <phase_6+0x74>
  4010d6: be 00 00 00 00       mov    $0x0,%esi
  4010db: eb 19                jmp    4010f6 <phase_6+0xa7>
  4010dd: 48 8b 52 08           mov    0x8(%rdx),%rdx
  4010e1: 83 c0 01              add    $0x1,%eax
  4010e4: 39 c8                 cmp    %ecx,%eax
  4010e6: 75 f5                 jne    4010dd <phase_6+0x8e>
  4010e8: 48 89 14 f4           mov    %rdx,(%rsp,%rsi,8)
  4010ec: 48 83 c6 01           add    $0x1,%rsi
  4010f0: 48 83 fe 06           cmp    $0x6,%rsi
  4010f4: 74 15                 je     40110b <phase_6+0xbc>
  4010f6: 8b 4c b4 30           mov    0x30(%rsp,%rsi,4),%ecx
  4010fa: b8 01 00 00 00        mov    $0x1,%eax
  4010ff: ba f0 32 60 00        mov    $0x6032f0,%edx
  401104: 83 f9 01              cmp    $0x1,%ecx
  401107: 7f d4                 jg     4010dd <phase_6+0x8e>
  401109: eb dd                 jmp    4010e8 <phase_6+0x99>
  40110b: 48 8b 1c 24           mov    (%rsp),%rbx
  40110f: 48 8b 44 24 08        mov    0x8(%rsp),%rax
  401114: 48 89 43 08           mov    %rax,0x8(%rbx)
  401118: 48 8b 54 24 10        mov    0x10(%rsp),%rdx
  40111d: 48 89 50 08           mov    %rdx,0x8(%rax)
  401121: 48 8b 44 24 18        mov    0x18(%rsp),%rax
  401126: 48 89 42 08           mov    %rax,0x8(%rdx)
  40112a: 48 8b 54 24 20        mov    0x20(%rsp),%rdx
  40112f: 48 89 50 08           mov    %rdx,0x8(%rax)
  401133: 48 8b 44 24 28        mov    0x28(%rsp),%rax
  401138: 48 89 42 08           mov    %rax,0x8(%rdx)
  40113c: 48 c7 40 08 00 00 00  movq   $0x0,0x8(%rax)
  401143: 00
  401144: bd 05 00 00 00        mov    $0x5,%ebp
  401149: eb 09                 jmp    401154 <phase_6+0x105>
  40114b: 48 8b 5b 08           mov    0x8(%rbx),%rbx
  40114f: 83 ed 01              sub    $0x1,%ebp
  401152: 74 11                 je     401165 <phase_6+0x116>
  401154: 48 8b 43 08           mov    0x8(%rbx),%rax
  401158: 8b 00                 mov    (%rax),%eax
  40115a: 39 03                 cmp    %eax,(%rbx)
  40115c: 7d ed                 jge    40114b <phase_6+0xfc>
  40115e: e8 2c 02 00 00        callq  40138f <explode_bomb>
  401163: eb e6                 jmp    40114b <phase_6+0xfc>
  401165: 48 83 c4 50           add    $0x50,%rsp
  401169: 5b                    pop    %rbx
  40116a: 5d                    pop    %rbp
  40116b: 41 5c                 pop    %r12
  40116d: 41 5d                 pop    %r13
  40116f: 41 5e                 pop    %r14
  401171: c3                    retq
```

It has '`read_six_number`' function. So, it's get 6 interger numbers as input.

```
  401065: 4c 8d 64 24 30        lea    0x30(%rsp),%r12
  40106a: 4d 89 e5              mov    %r12,%r13
  40106d: 41 be 00 00 00 00     mov    $0x0,%r14d
  401073: eb 26                 jmp    40109b <phase_6+0x4c>
```

After input, store `0x30(%rsp)` at `%r12` and `%r13`, store `0x0` at `%r14d`. Then jump to `40109b`.

```
  40109b: 4c 89 ed              mov    %r13,%rbp
  40109e: 41 8b 45 00           mov    0x0(%r13),%eax
  4010a2: 83 e8 01              sub    $0x1,%eax
  4010a5: 83 f8 05              cmp    $0x5,%eax
  4010a8: 77 cb                 ja     401075 <phase_6+0x26>
```

Store starting address of argument at `%rbp`, value of first argument at `%eax`. Compared with `(%eax) - 1` and 5, if `(%eax) - 1` is greater than `5`, then jump to address that calls `expode_bomb`. There for the first arguments is less than or equal `6`.

I interpreted each part separately.

There is double loop statement.

> 4010aa < : Check outer loop condition

```
 4010aa: 41 83 c6 01            add    $0x1,%r14d
 4010ae: 41 83 fe 06            cmp    $0x6,%r14d
 4010b2: 74 05                  je     4010b9 <phase_6+0x6a>
 4010b4: 44 89 f3               mov    %r14d,%ebx
 4010b7: eb cb                  jmp    401084 <phase_6+0x35>
```

`%r14d = %r14d + 1`

Compared this with `6`, if they are same jump to `4010b9`

else (not same) store `%r14d`at `%ebx` and jump to `401084`

`%r14d` is number of iterations outer loop.

> 401084 < : Body of outer loop

```
 401084: 48 63 c3               movslq %ebx,%rax
 401087: 8b 44 84 30            mov    0x30(%rsp,%rax,4),%eax
 40108b: 39 45 00               cmp    %eax,0x0(%rbp)
 40108e: 75 ec                  jne    40107c <phase_6+0x2d>
 401090: e8 fa 02 00 00         callq  40138f <explode_bomb>
```

Store value of `0x30(%rsp, %rax, 4)` that value moved `%rax (%r14d at 4010aa)` from `%rsp` at `%eax`. So, it is `(%rax)`th value in array

Compare this with first arguments, if they are not same jump to `40107c`, else (same) calls `expode_bomb`.

> 40107c < : Check inner loop condition

```
 40107c: 83 c3 01               add    $0x1,%ebx
 40107f: 83 fb 05               cmp    $0x5,%ebx
 401082: 7f 13                  jg     401097 <phase_6+0x48>
```

`%ebx = %ebx + 1`

Compare this with 5, if greater than `5`, jump to `401097`. Else repeat `401084`.

`%ebx` is number of iterations outer loop.

> 401097 < : Body of inner loop

```
 401097: 49 83 c5 04            add    $0x4,%r13
 40109b: 4c 89 ed               mov    %r13,%rbp
 40109e: 41 8b 45 00            mov    0x0(%r13),%eax
 4010a2: 83 e8 01               sub    $0x1,%eax
 4010a5: 83 f8 05               cmp    $0x5,%eax
 4010a8: 77 cb                  ja     401075 <phase_6+0x26>
 4010aa: 41 83 c6 01            add    $0x1,%r14d
 4010ae: 41 83 fe 06            cmp    $0x6,%r14d
 4010b2: 74 05                  je     4010b9 <phase_6+0x6a>
 4010b4: 44 89 f3               mov    %r14d,%ebx
 4010b7: eb cb                  jmp    401084 <phase_6+0x35>
```

Add `4` at `%rbp` to move address `4`, so move `1` index in array.

Check if it is in inner loop range. If out of range jump to `401075` that calls `expode_bomb`.

Else `%r14d = %r14d + 1`, and compare this with `6`. If they are same jump to `4010b9` (escape outer loop). else `%ebx = %r14d` and jump to `401084` (body of outer loop)

To sum it up, this is double loop statement that checks if there are equal values in the array.

> 4010b9 <

```
  4010b9: 49 8d 4c 24 18         lea    0x18(%r12),%rcx
  4010be: ba 07 00 00 00         mov    $0x7,%edx
  4010c3 …
```

`%rcx = (%r12) + 0x18 (== 32 == 8 * 4)`
`%edx = 7`

And execute `4010c3.`

> 4010c3 < : Store value of (7 - origin input value) at origin address

```
4010c3: 89 d0                  mov    %edx,%eax
4010c5: 41 2b 04 24            sub    (%r12),%eax
4010c9: 41 89 04 24            mov    %eax,(%r12)
4010cd: 49 83 c4 04            add    $0x4,%r12
4010d1: 4c 39 e1               cmp    %r12,%rcx
4010d4: 75 ed                  jne    4010c3 <phase_6+0x74>
4010d6: be 00 00 00 00         mov    $0x0,%esi
4010db: eb 19                  jmp    4010f6 <phase_6+0xa7>
```

`%eax = %edx = 7` (before 401069)
`%eax = %eax – ($r12)`
`(%r12) = eax`

`%r12 = %r12 + 0x4`, so move `1` index in array.

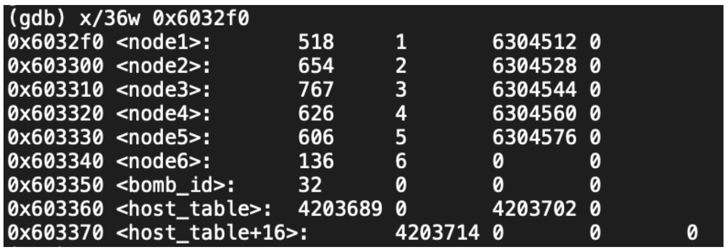
Compare `%r12` with `%rcx`, if they are not same jump to `4010c3` (repeat), else set `%esi` to `0` and jump to `4010f6`.

> 4010f6 < : Move in input value array

```
4010f6: 8b 4c b4 30            mov    0x30(%rsp,%rsi,4),%ecx
4010fa: b8 01 00 00 00         mov    $0x1,%eax
4010ff: ba f0 32 60 00         mov    $0x6032f0,%edx
401104: 83 f9 01               cmp    $0x1,%ecx
401107: 7f d4                  jg     4010dd <phase_6+0x8e>
401109: eb dd                  jmp    4010e8 <phase_6+0x99>
```

Store value of `0x30(%rsp, %rsi, 4)` that value moved `%rsi` (that set to `0` at `4010c3`) from `%rsp` at `%ecx`. So, it is `(%rsi)`th value in array
`%eax = 1`
`%edx = $0x6032f0`
`If ecx > 1`, jump to `4010dd`. Else jump to `4010e8`

What value will be stored at `$0x6032f0`?
I can guess that there would be array that has some six values because looping `6` times.



```
(gdb) x/36w 0x6032f0
0x6032f0 <node1>:       518     1       6304512 0
0x603300 <node2>:       654     2       6304528 0
0x603310 <node3>:       767     3       6304544 0
0x603320 <node4>:       626     4       6304560 0
0x603330 <node5>:       606     5       6304576 0
0x603340 <node6>:       136     6       0       0
0x603350 <bomb_id>:     32      0       0       0
0x603360 <host_table>:  4203689 0       4203702 0
0x603370 <host_table+16>:       4203714 0       0       0
```

It can confirm using the command `'x/32w 0x6032f0'`.
It was an array containing 6 nodes with the size of each node of 16 bytes and each value is 4 bytes.

> 4010dd < : move address

```
4010dd: 48 8b 52 08           mov    0x8(%rdx),%rdx
4010e1: 83 c0 01              add    $0x1,%eax
4010e4: 39 c8                 cmp    %ecx,%eax
4010e6: 75 f5                 jne    4010dd <phase_6+0x8e>
401038 …
```

%rdx = (%rdx) + 0x8
%eax = %eax + 1

If %eax is not equal to %ecx, jump to 4010dd (repeat). Else (same) execute 4010e8.

> 4010e8 < : store value of node and check loop condition

```
4010e8: 48 89 14 f4           mov    %rdx,(%rsp,%rsi,8)
4010ec: 48 83 c6 01           add    $0x1,%rsi
4010f0: 48 83 fe 06           cmp    $0x6,%rsi
4010f4: 74 15                 je     40110b <phase_6+0xbc>
4010f6 …
```

(%rsp, %rsi, 8) = rdx
%rsi = %rsi + 1

If %rsi is 6 (done to loop), jump to 40110b. Else execute 4010f6

> 40110b < : copy array that stored at %rsp

```
40110b: 48 8b 1c 24           mov    (%rsp),%rbx
40110f: 48 8b 44 24 08        mov    0x8(%rsp),%rax
401114: 48 89 43 08           mov    %rax,0x8(%rbx)
401118: 48 8b 54 24 10        mov    0x10(%rsp),%rdx
40111d: 48 89 50 08           mov    %rdx,0x8(%rax)
401121: 48 8b 44 24 18        mov    0x18(%rsp),%rax
401126: 48 89 42 08           mov    %rax,0x8(%rdx)
40112a: 48 8b 54 24 20        mov    0x20(%rsp),%rdx
40112f: 48 89 50 08           mov    %rdx,0x8(%rax)
401133: 48 8b 44 24 28        mov    0x28(%rsp),%rax
401138: 48 89 42 08           mov    %rax,0x8(%rdx)
40113c: 48 c7 40 08 00 00 00  movq   $0x0,0x8(%rax)
401143: 00
401144: bd 05 00 00 00        mov    $0x5,%ebp
401149: eb 09                 jmp    401154 <phase_6+0x105>
```

%rbx[0] = %rsp[0]
%rax = %rsp[1]
%rbx[1] = %rsp[1]
%rdx = %rsp[2]
%rax[1] = %rsp[2]
%rax = %rsp[3]
%rdx[1] = %rsp[3]
%rdx = %rsp[4]
%rax[1] = %rsp[4]
%rax = %rsp[5]
%rdx[1] = %rsp[5]
%rax[1] = 0
%ebp = 5

➜ %rbx [rsp[0], %%rsp[1]]   %rdx [%rsp[4], %rsp[5]] %rax [%rsp[5], 0]

> 401154 < : comparison of values attached to each other

```
401154: 48 8b 43 08           mov    0x8(%rbx),%rax
401158: 8b 00                 mov    (%rax),%eax
40115a: 39 03                 cmp    %eax,(%rbx)
40115c: 7d ed                 jge    40114b <phase_6+0xfc>
```

```
40115e: e8 2c 02 00 00          callq  40138f <explode_bomb>
401163: eb e6                   jmp    40114b <phase_6+0xfc>
```
If `(%rbx) >= eax = (%rbx) + 8`, jump to `40114b`.

Else calls `expode_bomb`.

So, the preceding value must be greater than or equal to the latter value.

`> 40114b < : check it iterations all done`
```
40114b: 48 8b 5b 08             mov    0x8(%rbx),%rbx
40114f: 83 ed 01                sub    $0x1,%ebp
401152: 74 11                   je     401165 <phase_6+0x116>
401154 …
```
`%rbx = %rbx + 8`

If `%ebp` is 1, jump to `401165`. Else execute `401154`

`> 401165 < : Done!`
```
401165: 48 83 c4 50             add    $0x50,%rsp
401169: 5b                      pop    %rbx
40116a: 5d                      pop    %rbp
40116b: 41 5c                   pop    %r12
40116d: 41 5d                   pop    %r13
40116f: 41 5e                   pop    %r14
401171: c3                      retq
```
Done!

To sum it up, it is a program that checks whether the value in the node is in descending order when the value of the input array is used as an index.

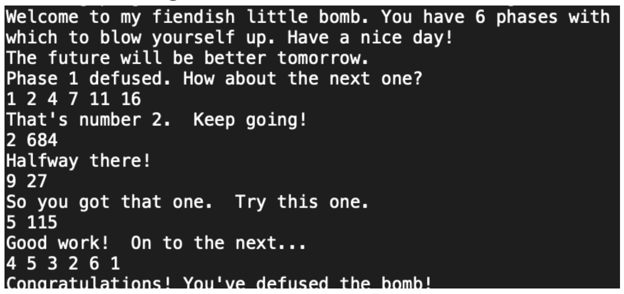
	node name	value	index	pointer to	
0x6032f0	<node1>:	518	1	6304512	0
0x603300	<node2>:	654	2	6304528	0
0x603310	<node3>:	767	3	6304544	0
0x603320	<node4>:	626	4	6304560	0
0x603330	<node5>:	606	5	6304576	0
0x603340	<node6>:	136	6	0	0

Sort `518 [1] 654[2] 767[3] 626[4] 606[5] 136[6]` with descending order,

result is `767[3] 654[2] 626[4] 606[5] 518[1] 136[6]`.   `value [index]`

So the answer should be **‘3 2 4 5 1 6’**

But I enter this, it exploded. Because I forget `4010c3` that store value of `(7 - origin input value)` at origin address.



```
Welcome to my fiendish little bomb. You have 6 phases with
which to blow yourself up. Have a nice day!
The future will be better tomorrow.
Phase 1 defused. How about the next one?
1 2 4 7 11 16
That's number 2.  Keep going!
2 684
Halfway there!
9 27
So you got that one.  Try this one.
5 115
Good work!  On to the next...
4 5 3 2 6 1
Congratulations! You've defused the bomb!
```

➜ So the input to dismantle this bomb is **‘4 5 3 2 6 1’**

! issue

I have some issue about screenshot.txt. I have done the assignment 6 times, so this file made by combine 6 terminal files. I did the assignment using `VScode`, but the length of terminal out was too long, so some results (about `phase_1`, `phase_6`) disappeared before I saved it.
I'm trying to reproduce previous procedure. I've added commands as soon as I can remember. This is indicated with # before the command in `‘screenshot32.txt’`.