Secure Systems and Pwning Popular Platforms

Modern Binary Exploitation

CSCI 4968 - Spring 2015

Markus Gaasedelen

```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
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                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
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                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
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                push    0Dh
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loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
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                call    sub_3140F3
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loc_31307D:                             ; CODE XREF: sub_312FD8
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                mov     [ebp+var_4], eax
```
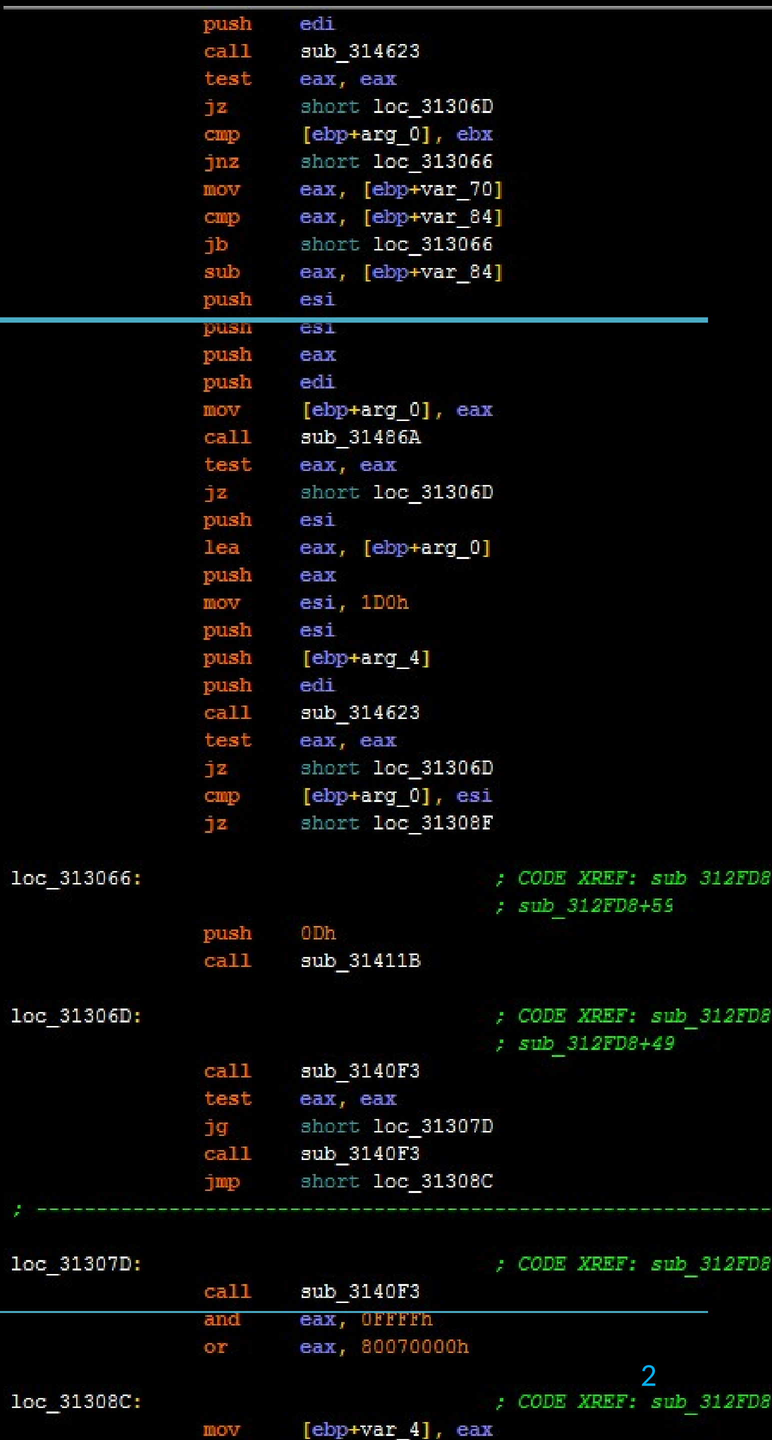

Lecture Overview

- Secure Systems & Patch Sets
  - OpenBSD
  - SELinux
  - Grsecurity
- Owning Game Consoles
  - Xbox 360
  - Nintendo 3DS
  - PS3
- Current Generation



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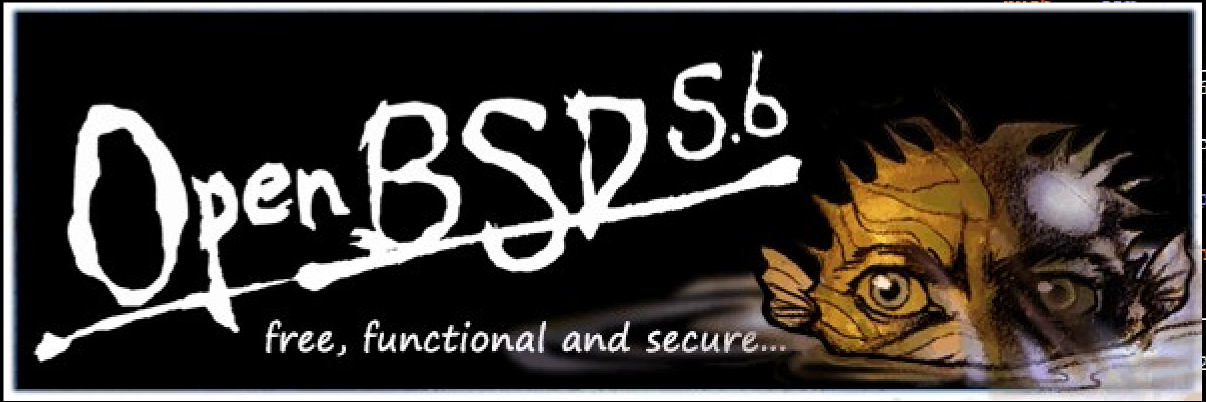
OpenBSD



"The OpenBSD project produces a **FREE**, multi-platform 4.4BSD-based UNIX-like operating system. Our efforts emphasize portability, standardization, correctness, proactive security and integrated cryptography."

–openbsd.org

OpenBSD

- Started in 1995 forking from NetBSD 1.0
- “Try to be the #1 most secure operating system” –openbsd.org

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push    edi
mov     [ebp+arg_0], eax
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test    eax, eax
jz      short loc_31306D
push    esi
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push    eax
mov     esi, 1D0h
        esi
        [ebp+arg_4]

                                  ; CODE XREF: sub_312FD8
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        short loc_31308C
-------------------------------------------------------------------

loc_3130.D:                       ; CODE XREF: sub_312FD8
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loc_31308C:                       ; CODE XREF: sub_312FD8
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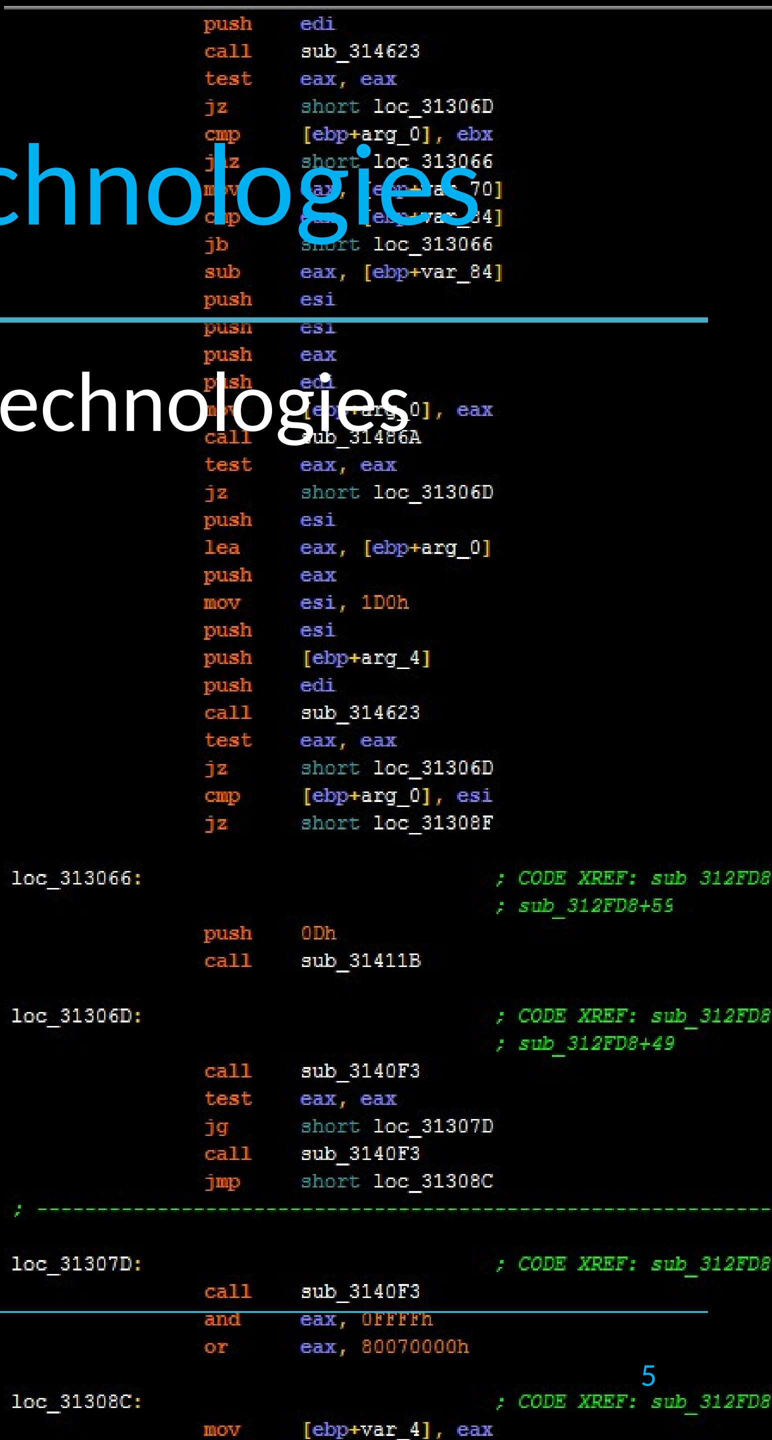
OpenBSD – Added Technologies

- Adds hardening & security technologies
  - W^X
  - Privilege isolation
  - Jails
  - Randomized malloc/mmap
  - Ships Crypto
  - A few other things



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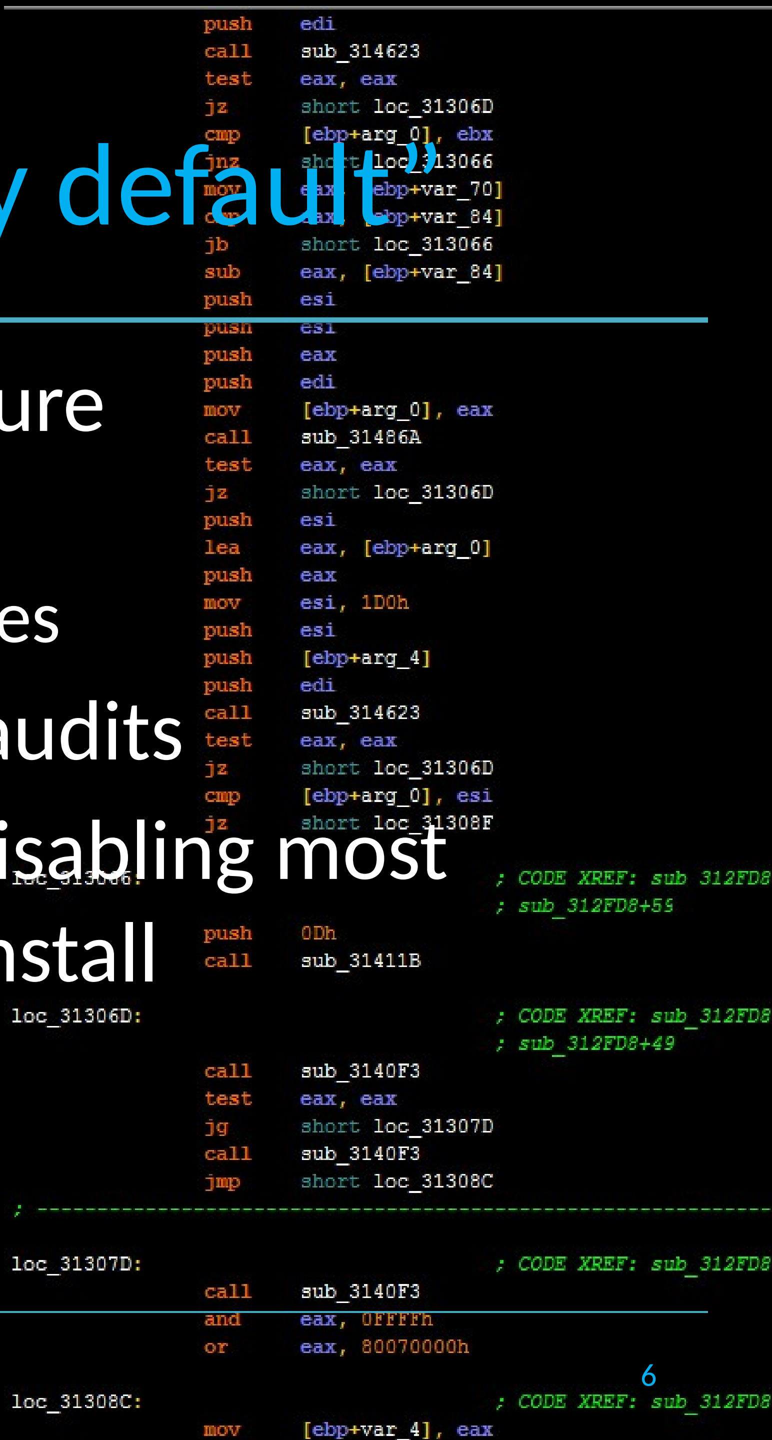
OpenBSD – “secure by default”

- Good code is inherently secure
  - – Fewer bugs
  - – Utilizes secure coding practices
- Extensive code review and audits
- Reduces attack surface by disabling most remote services in default install



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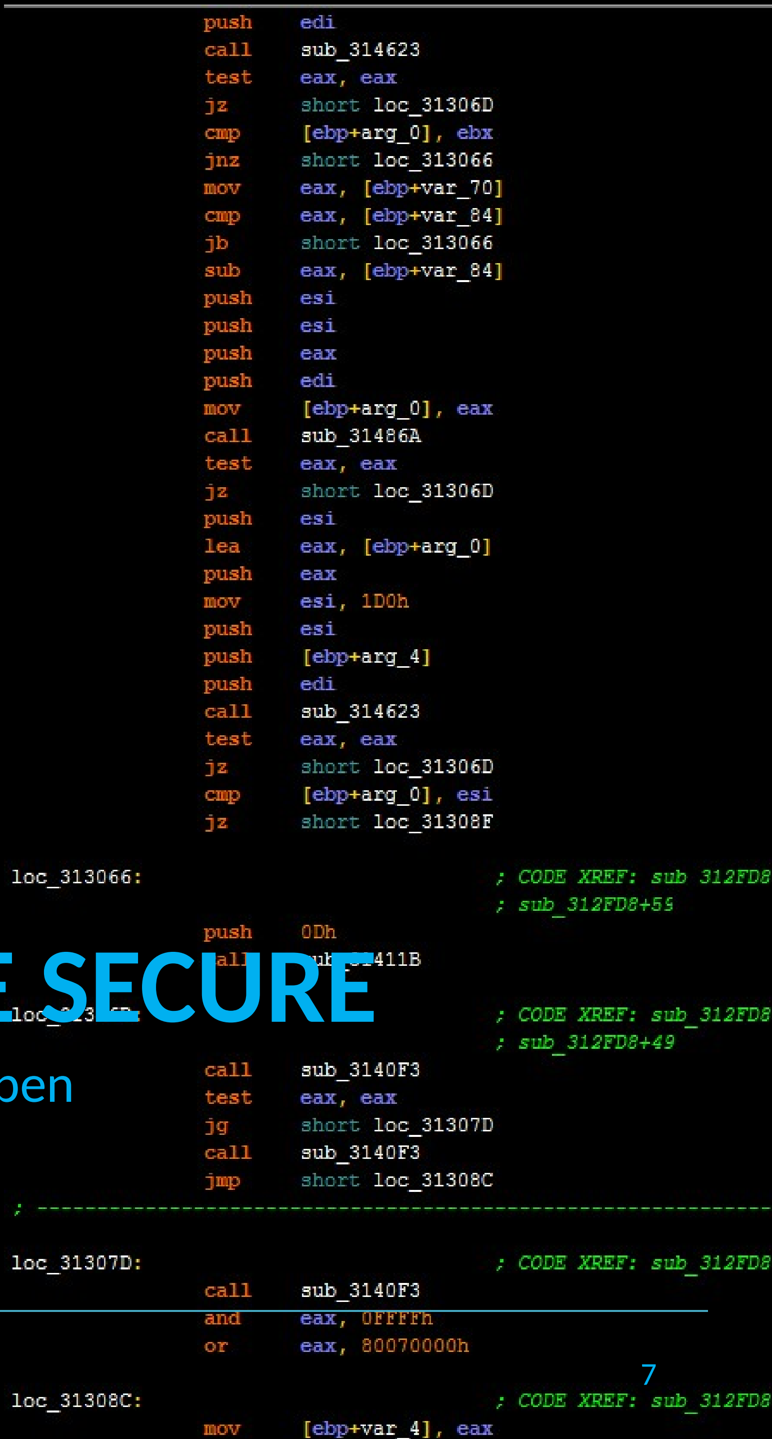
```

FEWER BUGS != MORE SECURE

One bug is still enough to blow things wide open



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                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
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                mov     [ebp+arg_0], eax
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                lea     eax, [ebp+arg_0]
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                push    [ebp+arg_4]
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```
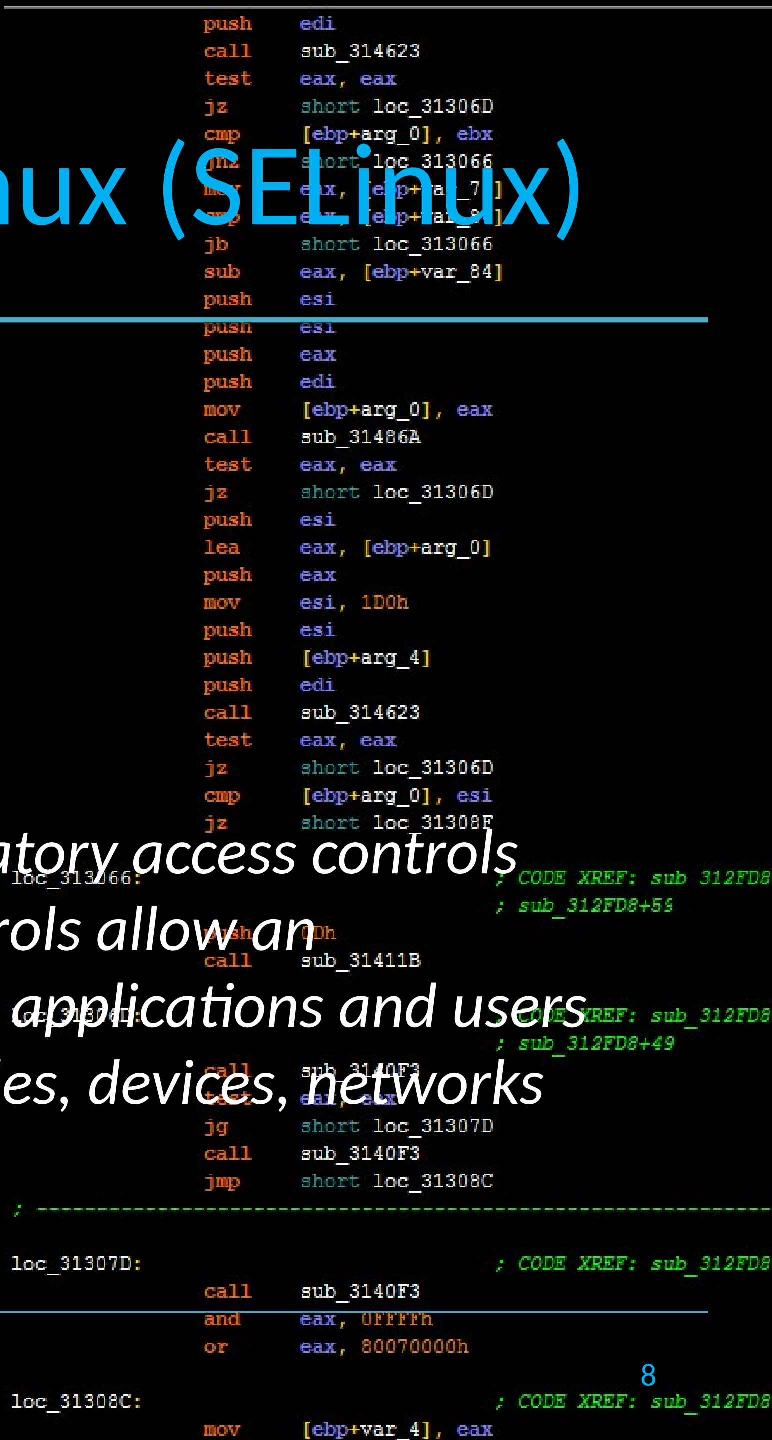

Security-Enhanced Linux (SELinux)

“SELinux is an implementation of mandatory access controls (MAC) on Linux. Mandatory access controls allow an administrator of a system to define how applications and users can access different resources such as files, devices, networks and inter-process communication.”

–selinuxproject.org



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                mov     eax, [ebp+[illegible]]
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```

SELinux – Overview

- Open sourced by the NSA in 2000
- Extended filesystem permissions controls
  - Users and services should only have access to exactly what they need

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                call    sub_314623
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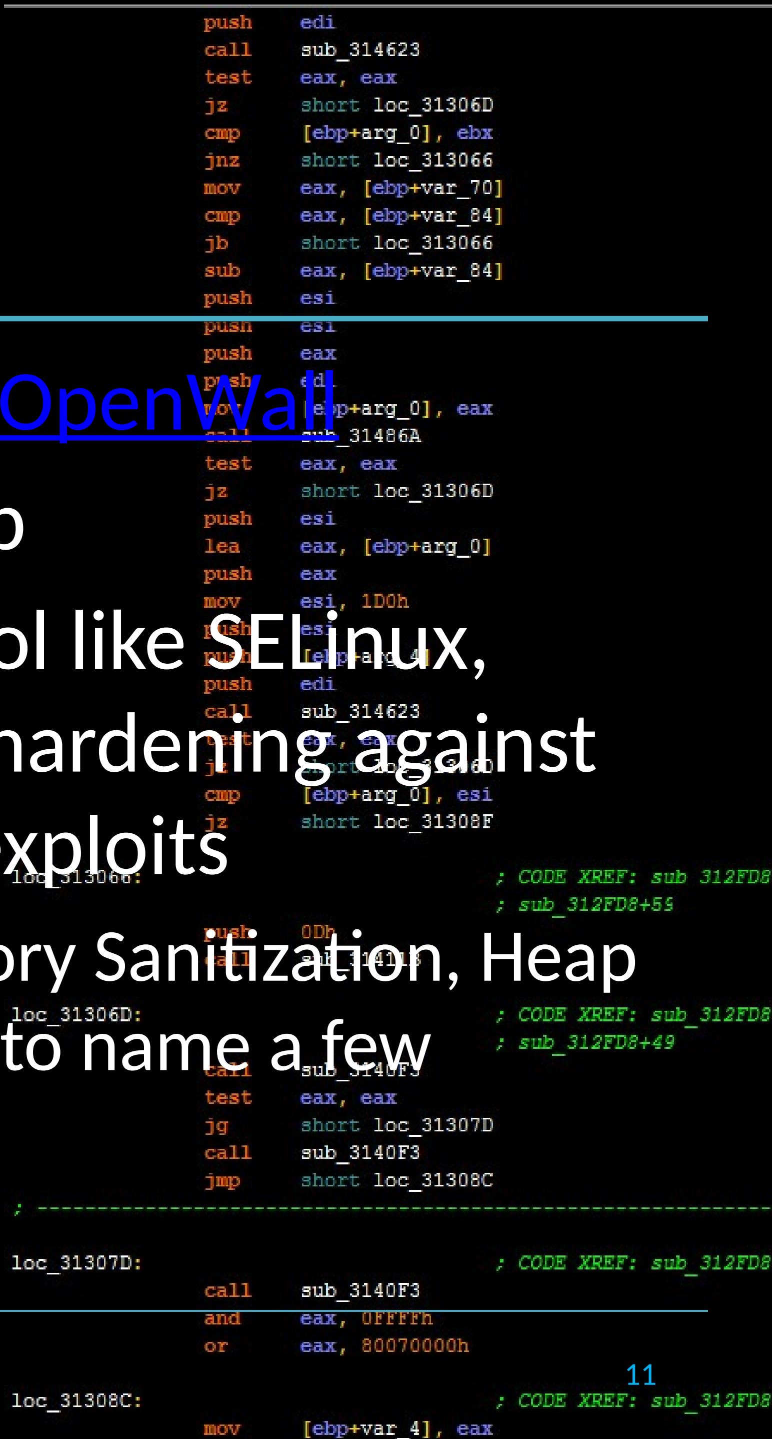
Grsecurity (GRSEC)

"Grsecurity is an extensive security enhancement to the Linux kernel that defends against a wide range of security threats through intelligent access control, memory corruption-based exploit prevention, and a host of other system hardening that generally require no configuration …"

–grsecurity.net

GRSEC – Overview

- Started in 2001 as a port of OpenWall
- Free, relatively easy to setup
- Besides robust access control like SELinux, GRSEC has a large focus on hardening against memory corruption based exploits
  - High quality PAX ASLR, Memory Sanitization, Heap Hardening, Active Response, to name a few



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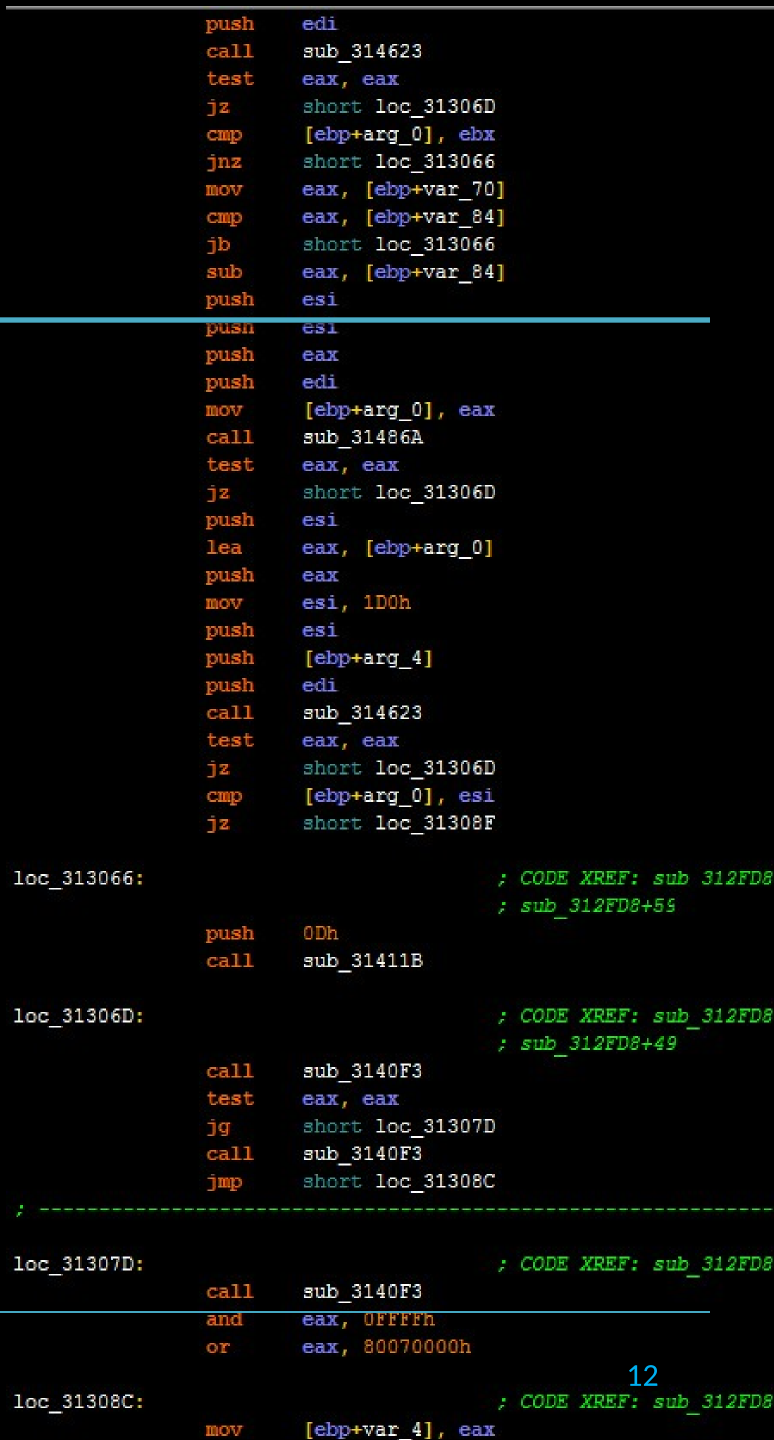

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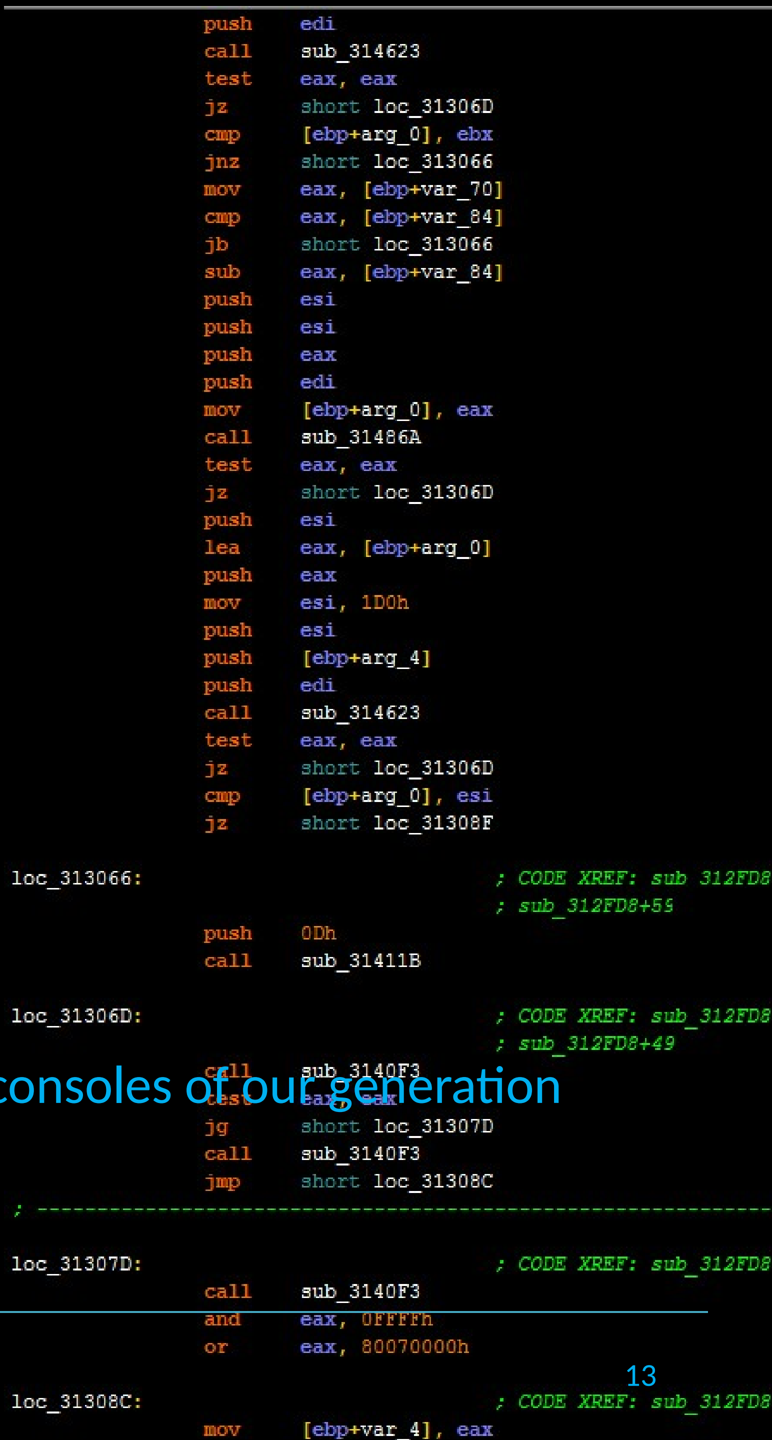
GAME CONSOLES

A closer look at the bugs that brought down consoles of our generation



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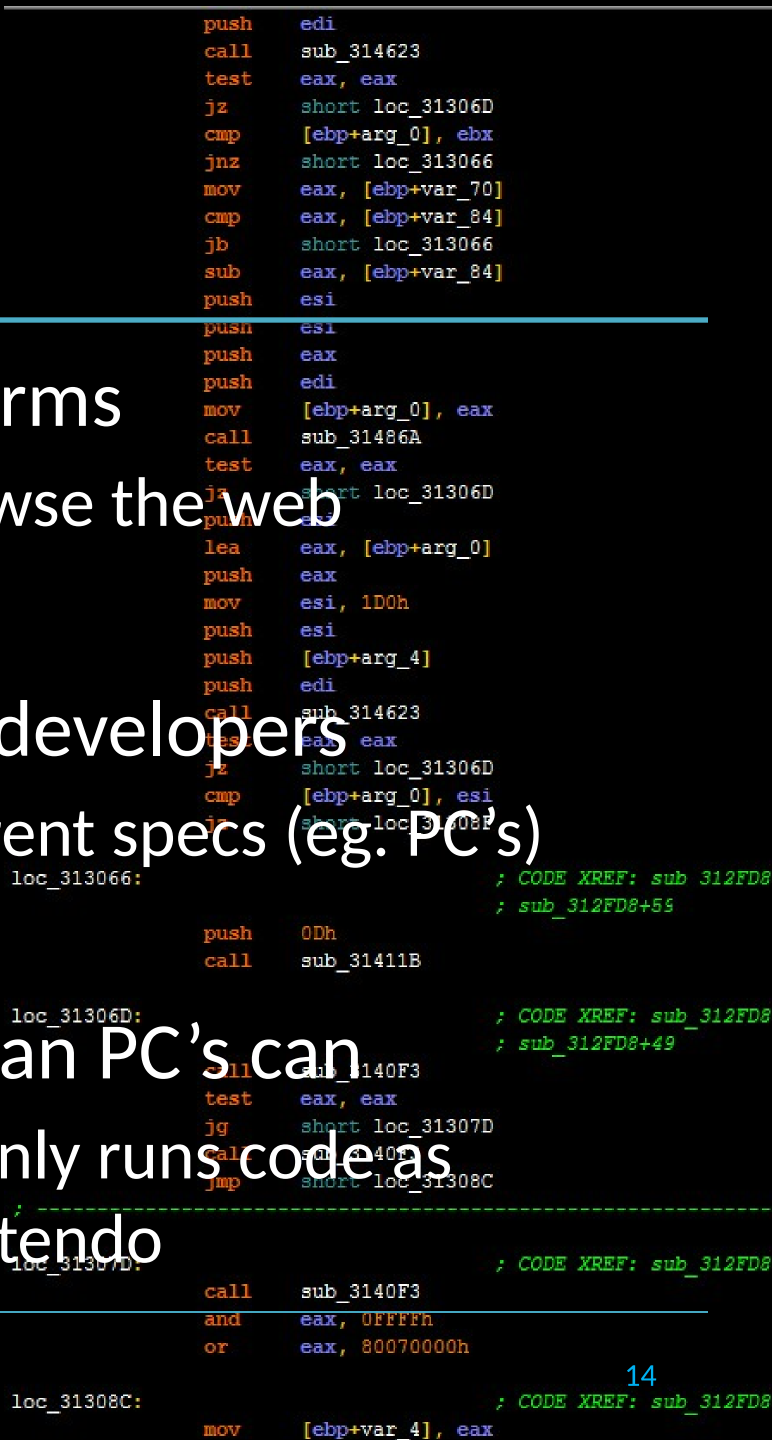
Game Consoles

- Evolving entertainment platforms
  - Play games, stream media, browse the web
- 100% consistent machine for developers
  - Don’t have to account for different specs (eg. PC’s)
- Enforces DRM much better than PC’s can
  - It’s a controlled platform that only runs code as blessed by Sony, Microsoft, Nintendo



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                and     eax, 0FFFFh
                or      eax, 80070000h
loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```
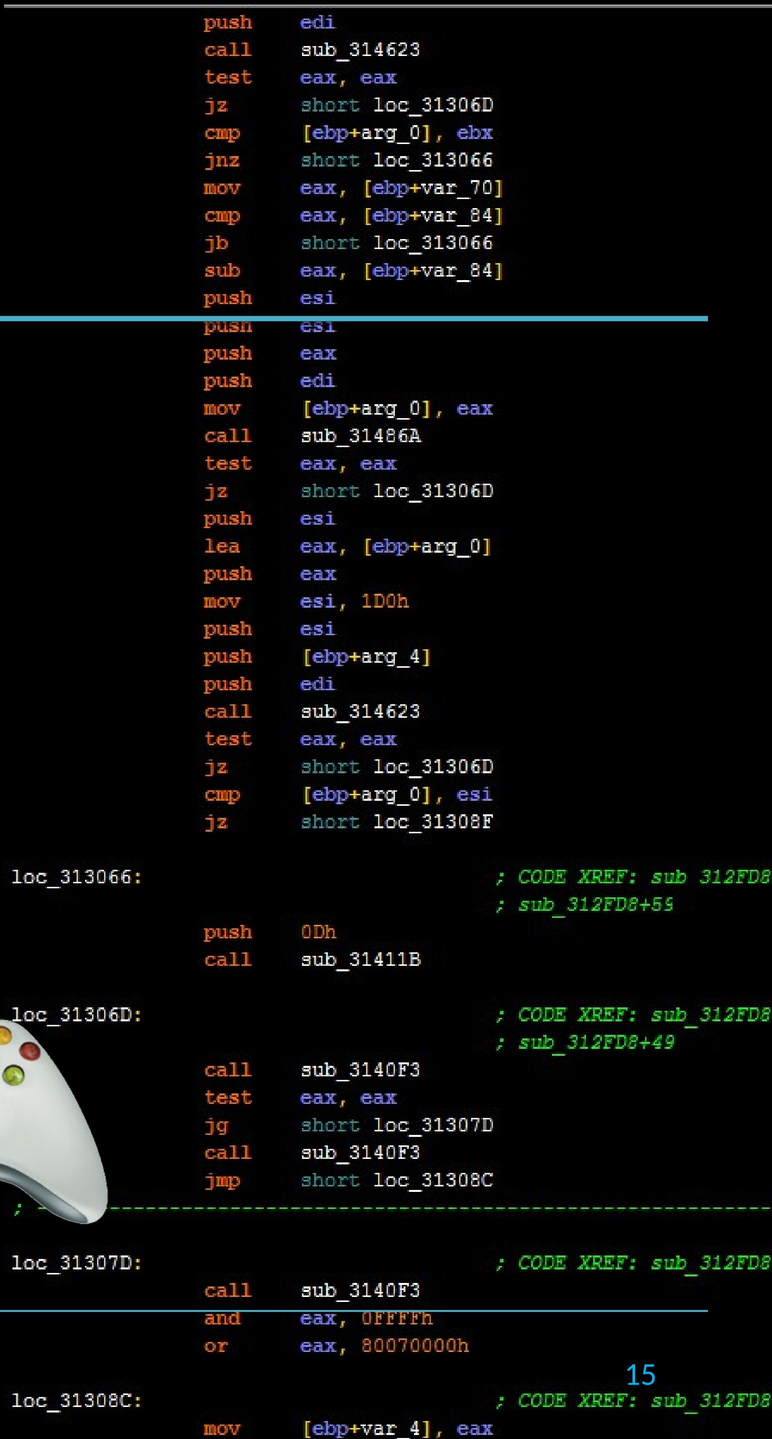
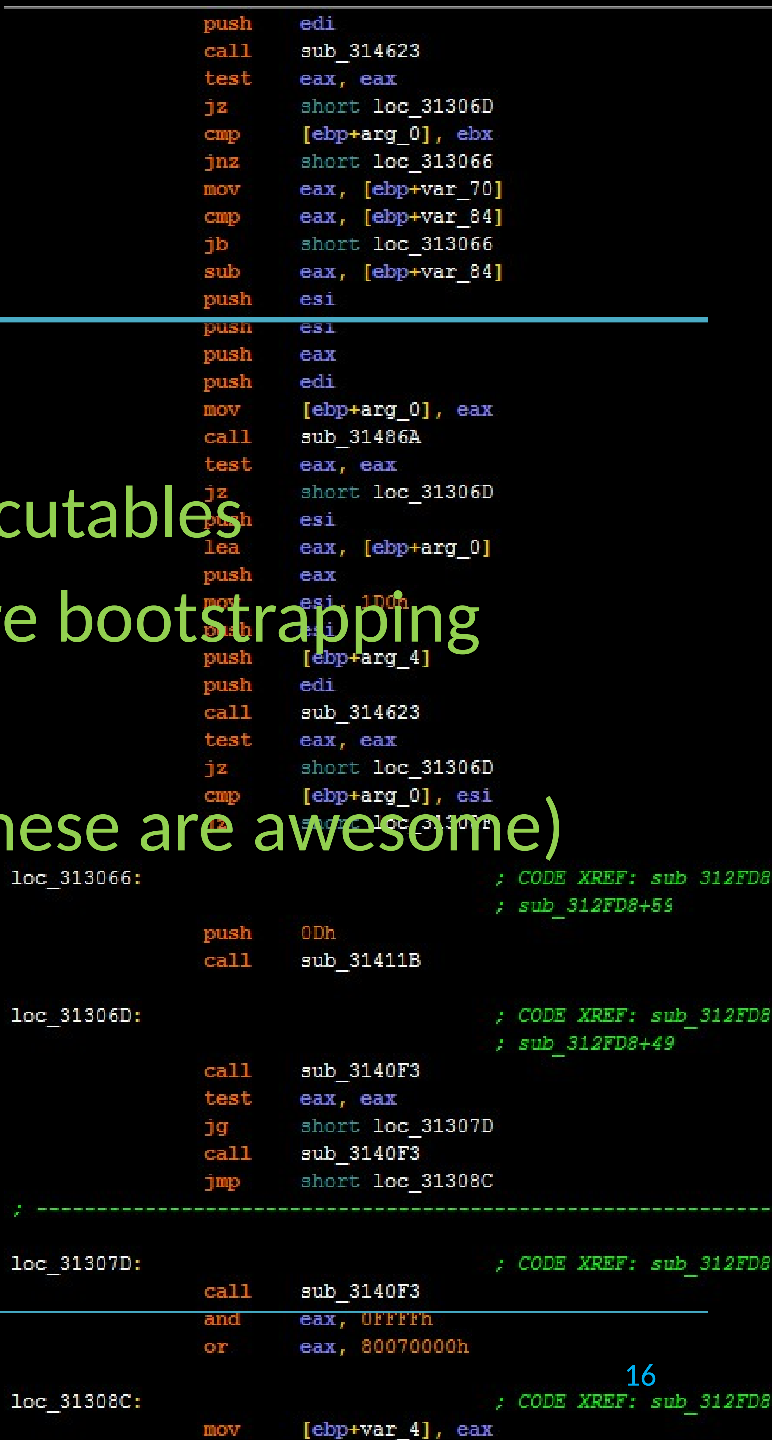

Xbox 360 – Nov. 2005



```
                  push    edi
                  call    sub_314623
                  test    eax, eax
                  jz      short loc_31306D
                  cmp     [ebp+arg_0], ebx
                  jnz     short loc_313066
                  mov     eax, [ebp+var_70]
                  cmp     eax, [ebp+var_84]
                  jb      short loc_313066
                  sub     eax, [ebp+var_84]
                  push    esi
                  push    esi
                  push    eax
                  push    edi
                  mov     [ebp+arg_0], eax
                  call    sub_31486A
                  test    eax, eax
                  jz      short loc_31306D
                  push    esi
                  lea     eax, [ebp+arg_0]
                  push    eax
                  mov     esi, 1D0h
                  push    esi
                  push    [ebp+arg_4]
                  push    edi
                  call    sub_314623
                  test    eax, eax
                  jz      short loc_31306D
                  cmp     [ebp+arg_0], esi
                  jz      short loc_31308F

loc_313066:                                  ; CODE XREF: sub_312FD8
                                             ; sub_312FD8+55
                  push    0Dh
                  call    sub_31411B

loc_31306D:                                  ; CODE XREF: sub_312FD8
                                             ; sub_312FD8+49
                  call    sub_3140F3
                  test    eax, eax
                  jg      short loc_31307D
                  call    sub_3140F3
                  jmp     short loc_31308C
; ---------------------------------------------------------------------

loc_31307D:                                  ; CODE XREF: sub_312FD8
                  call    sub_3140F3
                  and     eax, 0FFFFh
                  or      eax, 80070000h

loc_31308C:                                  ; CODE XREF: sub_312FD8
                  mov     [ebp+var_4], eax
```

Xbox 360 – Nov. 2005

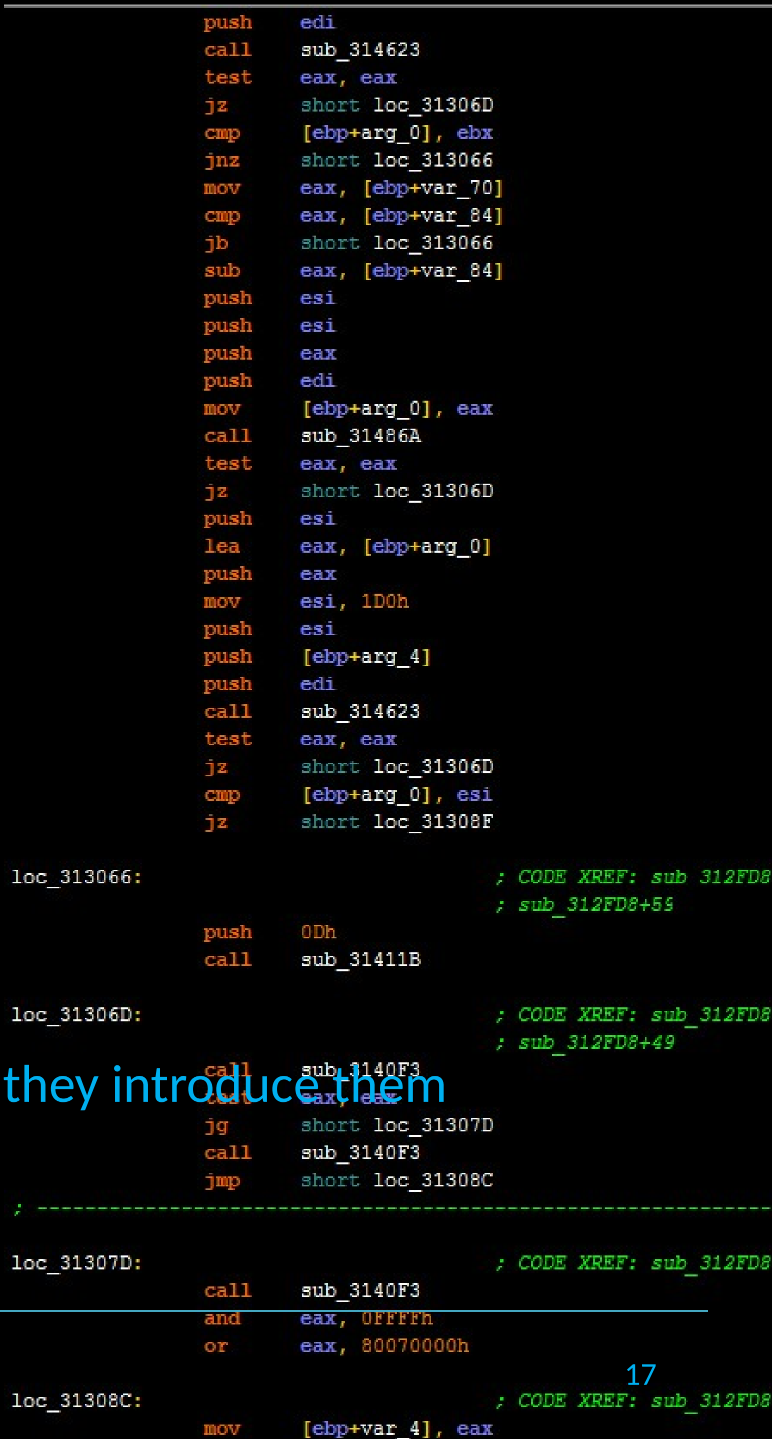
- Security Perspective
  - Only runs signed code or executables
  - Rigorous chain of trust, secure bootstrapping
  - Encrypted runtime memory
  - eFuses to enforce updates (these are awesome)
  - NX/DEP
  - No ASLR



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_3130[illegible]

loc_313066:                                 ; CODE XREF: sub_312FD8
                                            ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                                 ; CODE XREF: sub_312FD8
                                            ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                                 ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                                 ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

KING KONG EXPLOIT

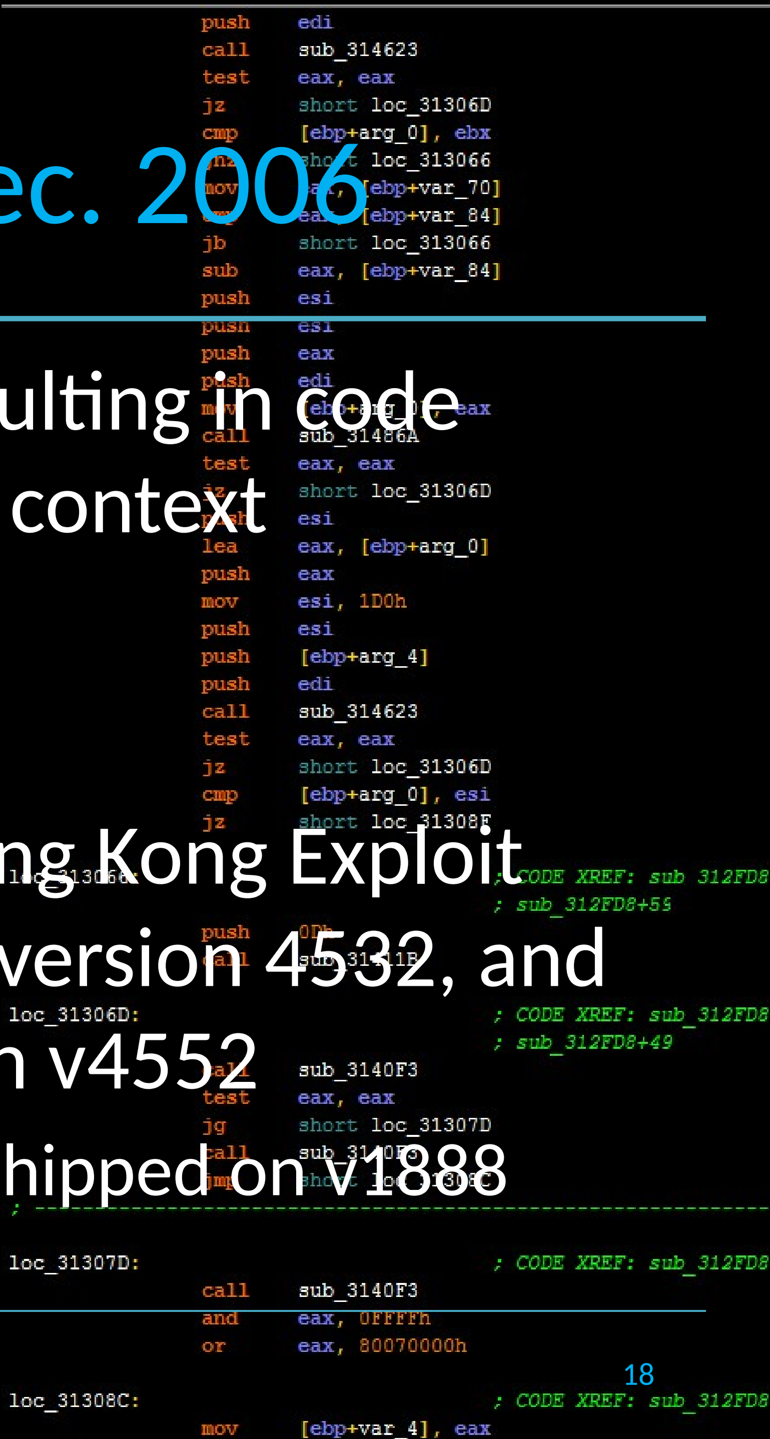
updates don’t always patch bugs, sometimes they introduce them



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

King Kong Exploit – Dec. 2006

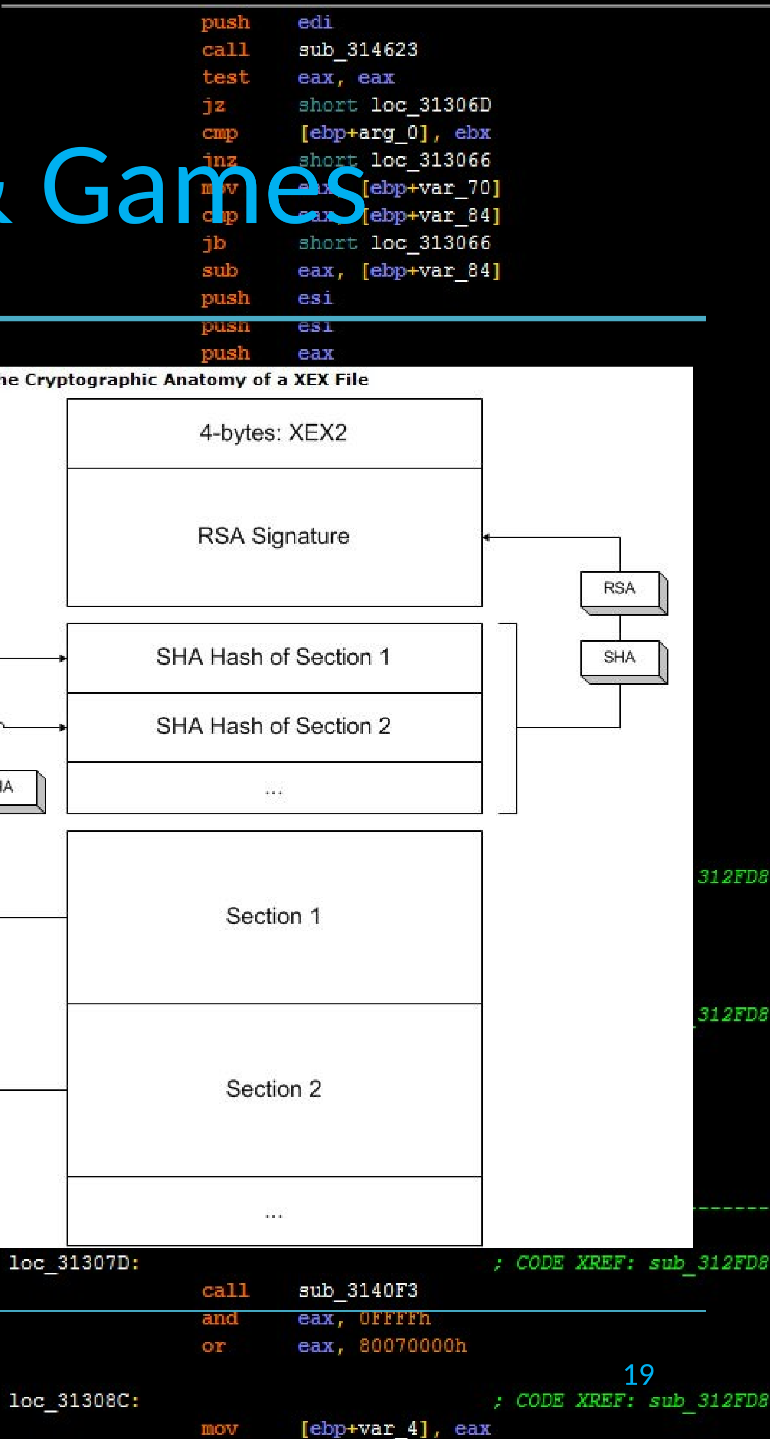
- Privilege escalation bug, resulting in code execution at the Hypervisor context
  - Complete system control
- The bug leveraged by the King Kong Exploit was INTRODUCED in kernel version 4532, and patched two updates later in v4552
  - For reference, the Xbox 360 shipped on v1888



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_3141 1B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_3130 8C
; ---------------------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

About the Xbox 360 & Games

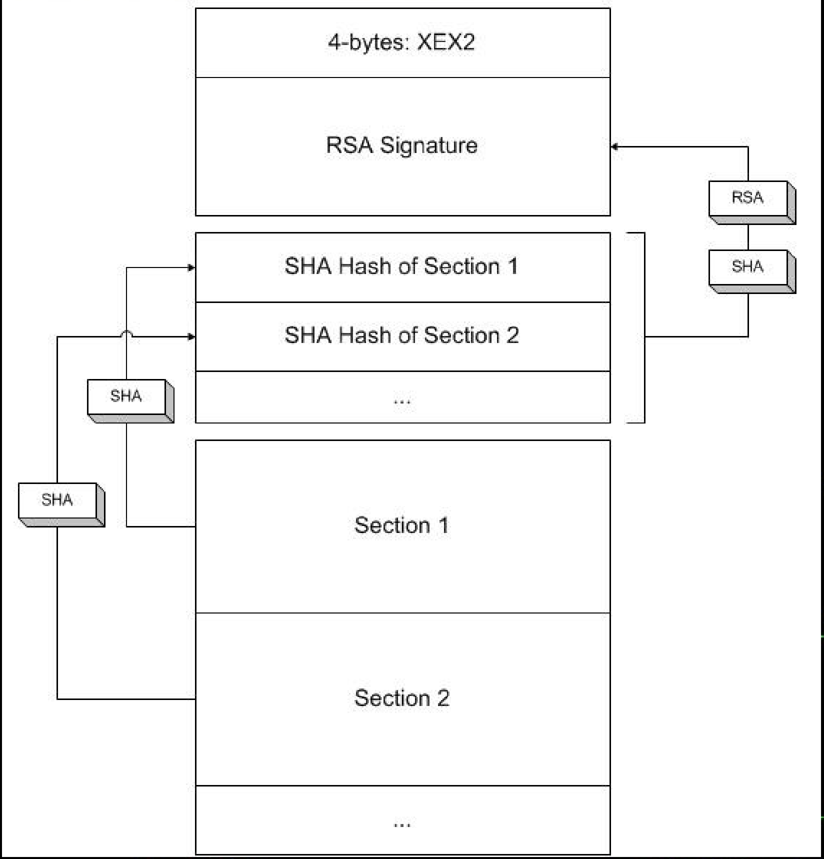
- All executables (.XEX's) are signed by Microsoft which the system verifies to prevent tampering with code
- Data assets such as textures, models, shaders, and audio as used by games are NOT signed!
  - Find bugs in game asset parsers



```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_70]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
push    esi
push    eax
```

```
loc_31307D:                          ; CODE XREF: sub_312FD8
call    sub_3140F3
and     eax, 0FFFFh
or      eax, 80070000h

loc_31308C:                          ; CODE XREF: sub_312FD8
mov     [ebp+var_4], eax
```

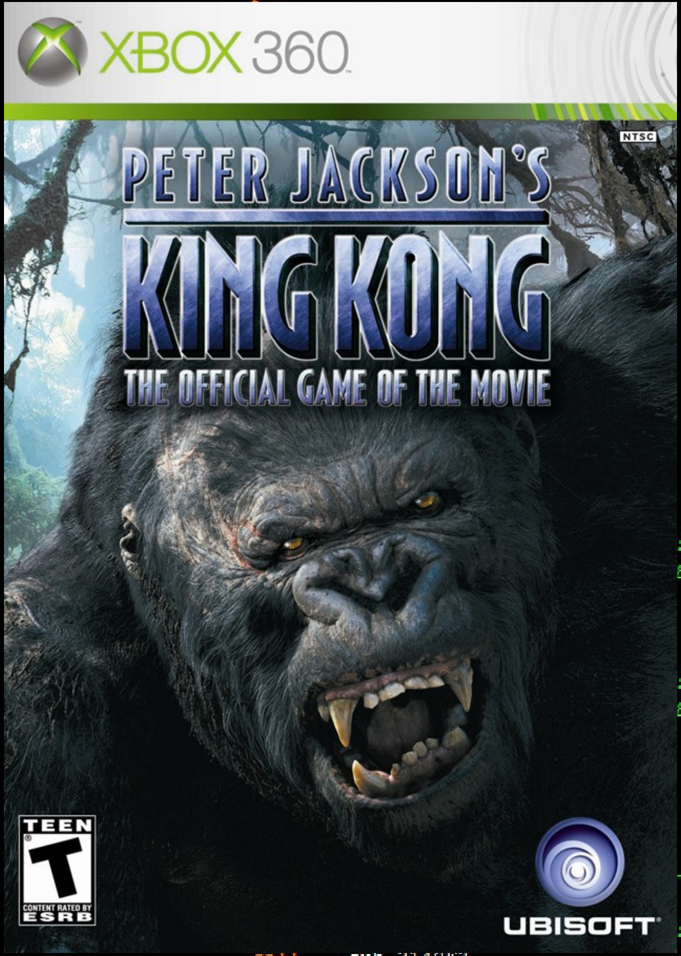
Figure 1. The Cryptographic Anatomy of a XEX File



Stage One: King Kong's Role

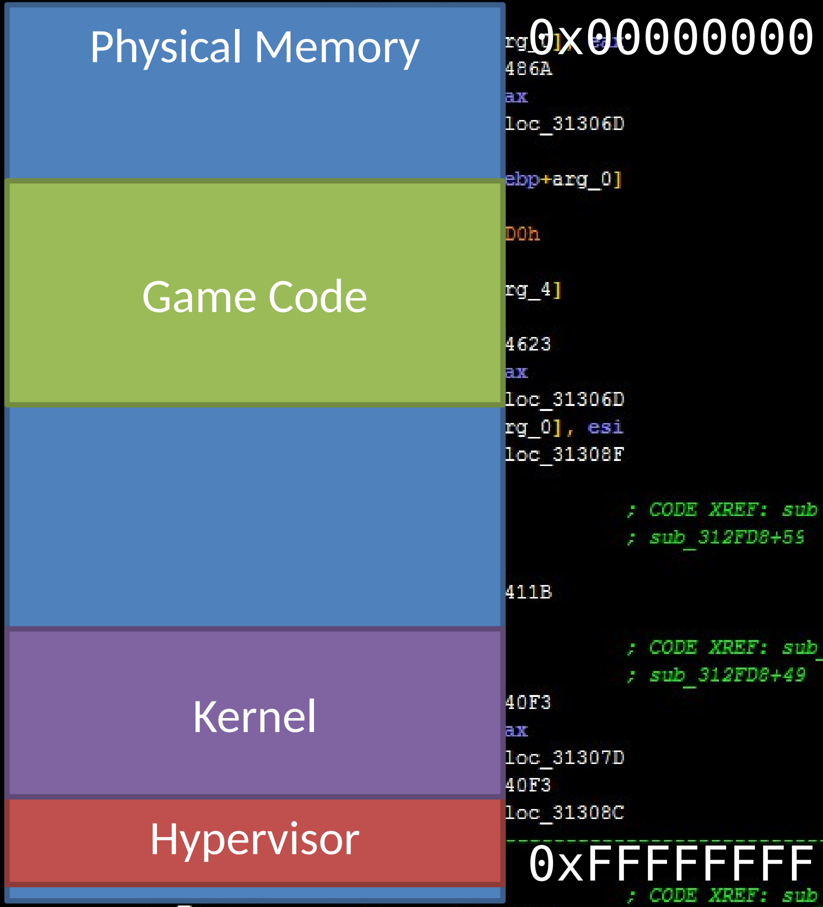
- A maliciously crafted unsigned shader file parsed by the signed King Kong game XEX, can lead to <u>unprivileged code execution</u> on the system

- King Kong was one of many possible memory corruption vectors that could have been used to get basic code exec



About the Xbox 360 Hypervisor

- A small Hypervisor (Hv) sits next to the kernel, near the top of memory
- The Hv handles some crypto keys, low level IO, memory encryption/decryption operations and more
- If you can take over the Hv, you have access to physmem and the highest privilege of execution



```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_70]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
push    esi
push    eax
```

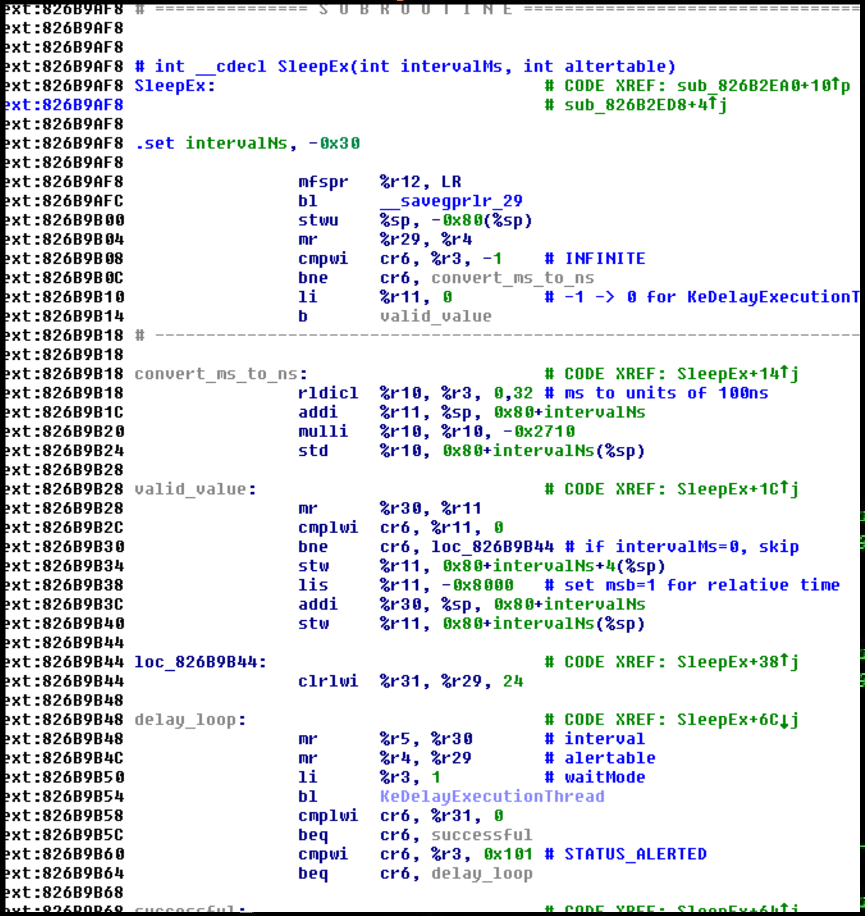
```
call    sub_3140F3
and     eax, 0FFFFh
or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
mov     [ebp+var_4], eax
```

Stage Two: Hyper Escalation

- The PPC instruction ‘sc’ is used to make system calls on the Xbox 360, the Hv handles these calls as they are made

- Unfortunately, along came a bug in the syscall handler):

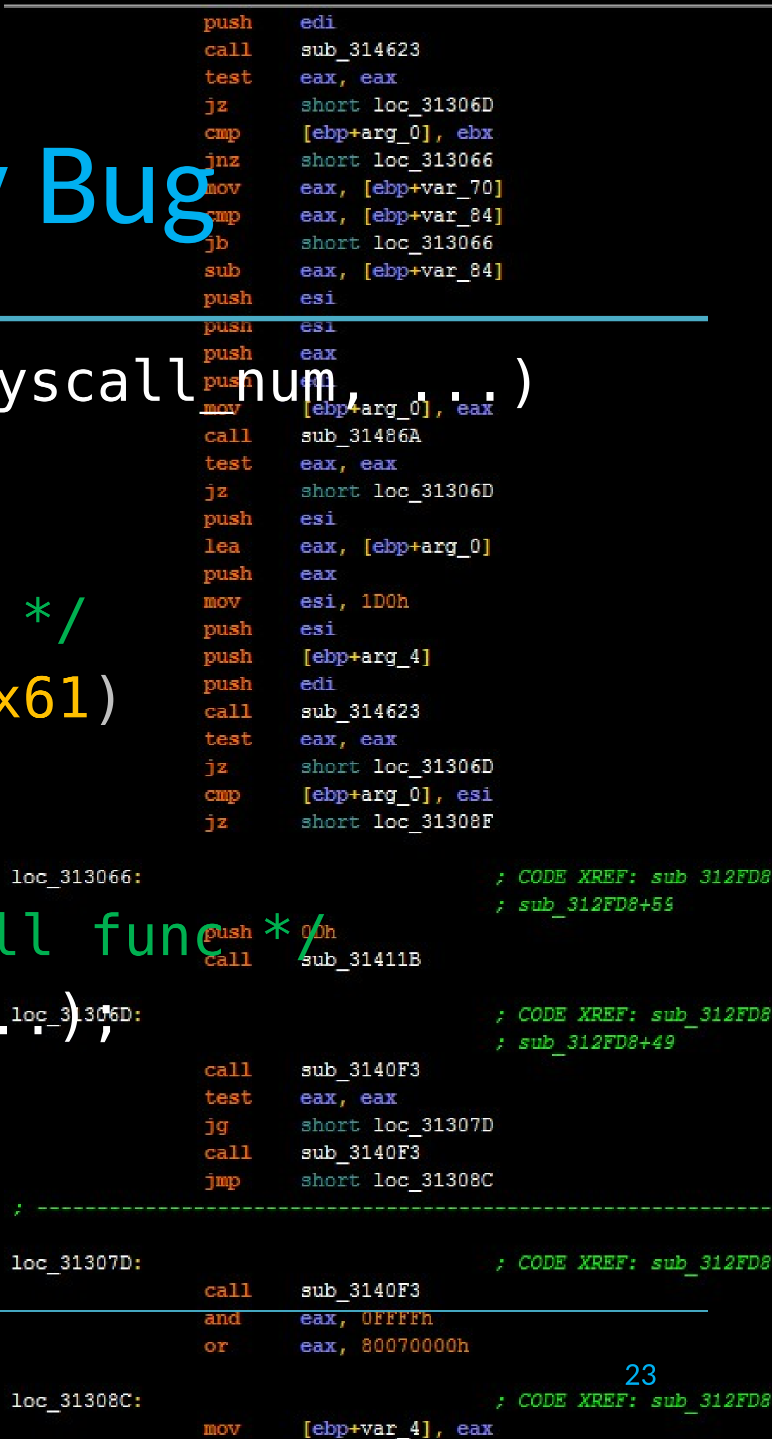
  random ppc -------------->



```
ext:826B9AF8 # =============== S U B R O U T I N E ================================
ext:826B9AF8
ext:826B9AF8
ext:826B9AF8 # int __cdecl SleepEx(int intervalMs, int altertable)
ext:826B9AF8 SleepEx:                               # CODE XREF: sub_826B2EA0+10↑p
ext:826B9AF8                                        # sub_826B2ED8+4↑j
ext:826B9AF8
ext:826B9AF8 .set intervalNs, -0x30
ext:826B9AF8
ext:826B9AF8                 mfspr   %r12, LR
ext:826B9AFC                 bl      __savegprlr_29
ext:826B9B00                 stwu    %sp, -0x80(%sp)
ext:826B9B04                 mr      %r29, %r4
ext:826B9B08                 cmpwi   cr6, %r3, -1     # INFINITE
ext:826B9B0C                 bne     cr6, convert_ms_to_ns
ext:826B9B10                 li      %r11, 0          # -1 -> 0 for KeDelayExecutionT
ext:826B9B14                 b       valid_value
ext:826B9B18 # ---------------------------------------------------------------------
ext:826B9B18
ext:826B9B18 convert_ms_to_ns:                      # CODE XREF: SleepEx+14↑j
ext:826B9B18                 rldicl  %r10, %r3, 0,32 # ms to units of 100ns
ext:826B9B1C                 addi    %r11, %sp, 0x80+intervalNs
ext:826B9B20                 mulli   %r10, %r10, -0x2710
ext:826B9B24                 std     %r10, 0x80+intervalNs(%sp)
ext:826B9B28
ext:826B9B28 valid_value:                           # CODE XREF: SleepEx+1C↑j
ext:826B9B28                 mr      %r30, %r11
ext:826B9B2C                 cmplwi  cr6, %r11, 0
ext:826B9B30                 bne     cr6, loc_826B9B44 # if intervalMs=0, skip
ext:826B9B34                 stw     %r11, 0x80+intervalNs+4(%sp)
ext:826B9B38                 lis     %r11, -0x8000    # set msb=1 for relative time
ext:826B9B3C                 addi    %r30, %sp, 0x80+intervalNs
ext:826B9B40                 stw     %r11, 0x80+intervalNs(%sp)
ext:826B9B44
ext:826B9B44 loc_826B9B44:                          # CODE XREF: SleepEx+38↑j
ext:826B9B44                 clrlwi  %r31, %r29, 24
ext:826B9B48
ext:826B9B48 delay_loop:                            # CODE XREF: SleepEx+6C↓j
ext:826B9B48                 mr      %r5, %r30        # interval
ext:826B9B4C                 mr      %r4, %r29        # alertable
ext:826B9B50                 li      %r3, 1           # waitMode
ext:826B9B54                 bl      KeDelayExecutionThread
ext:826B9B58                 cmplwi  cr6, %r31, 0
ext:826B9B5C                 beq     cr6, successful
ext:826B9B60                 cmpwi   cr6, %r3, 0x101 # STATUS_ALERTED
ext:826B9B64                 beq     cr6, delay_loop
ext:826B9B68
ext:826B9B68 successful:                            # CODE XREF: SleepEx+64↑j
```

Pseudocode of the Hv Bug

```
int syscall_handler(uint64_t syscall_num, ...)
{

  /* check for invalid syscall */
  if((uint32_t)syscall_num > 0x61)
    return 0;

  /* call the respective syscall func */
  syscall_table[syscall_num](...);

  ...
}
```



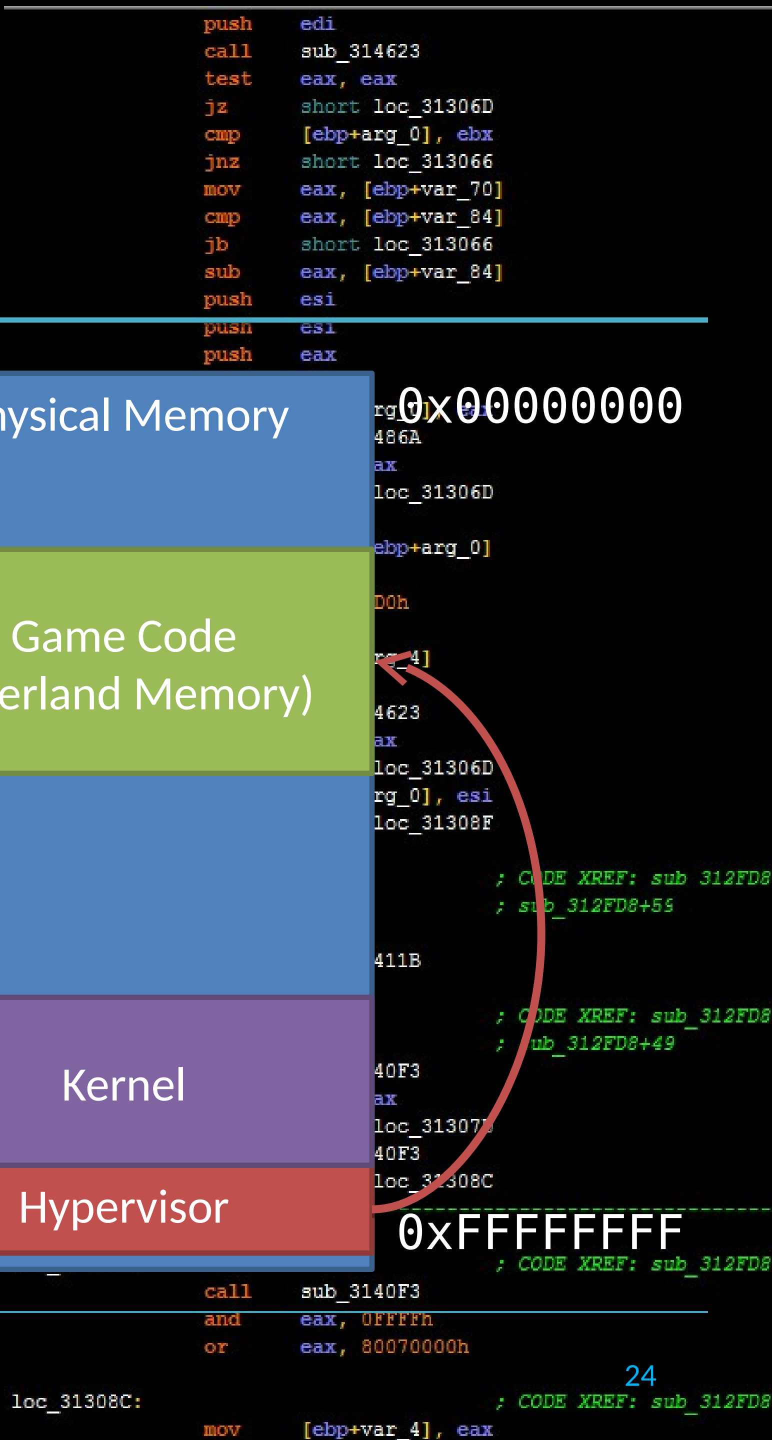
```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

The Oops

- Only the lower 32 bits of the syscall number are sanity checked
- The whole 64 bit number is used in address calculation

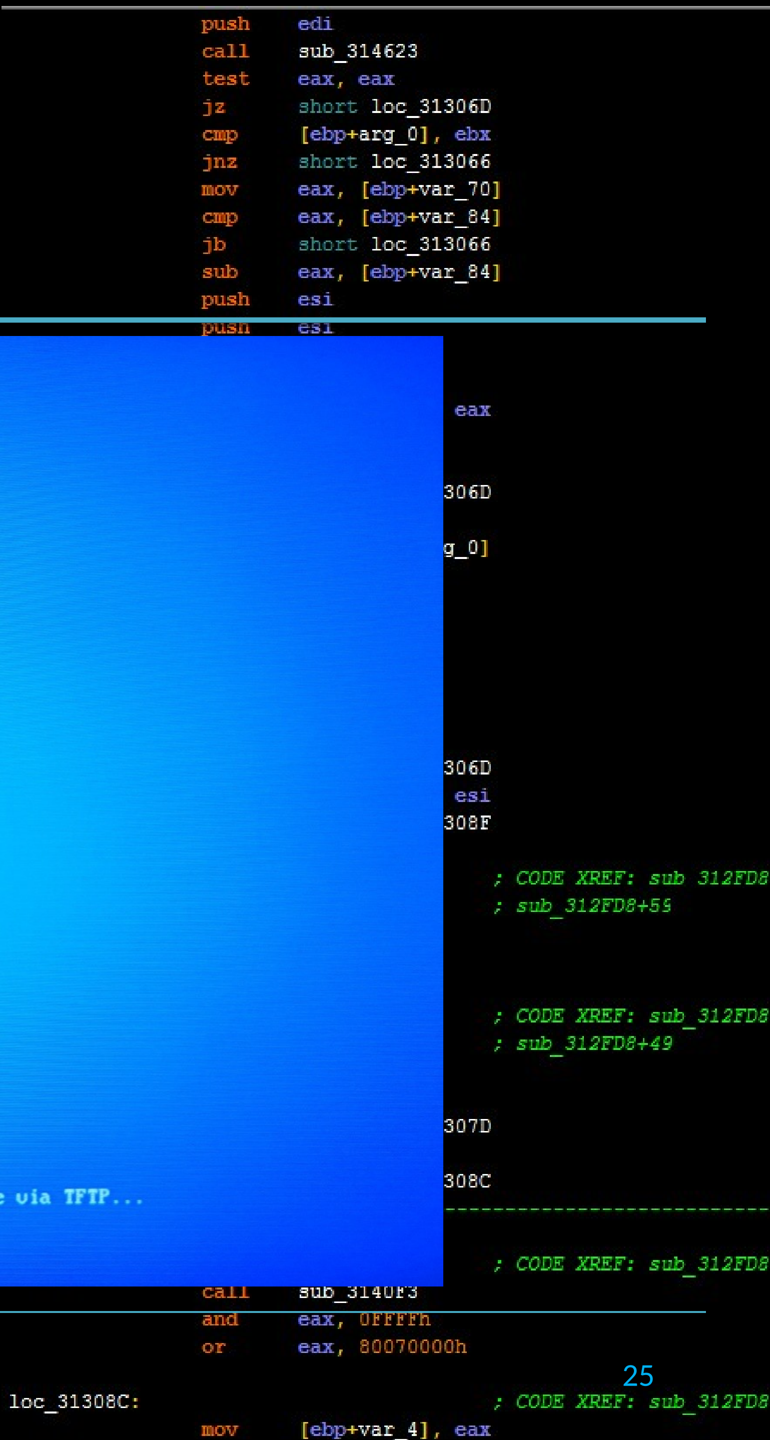
```
syscall_table[syscall_num](...);
```

Just jump to userland memory/code

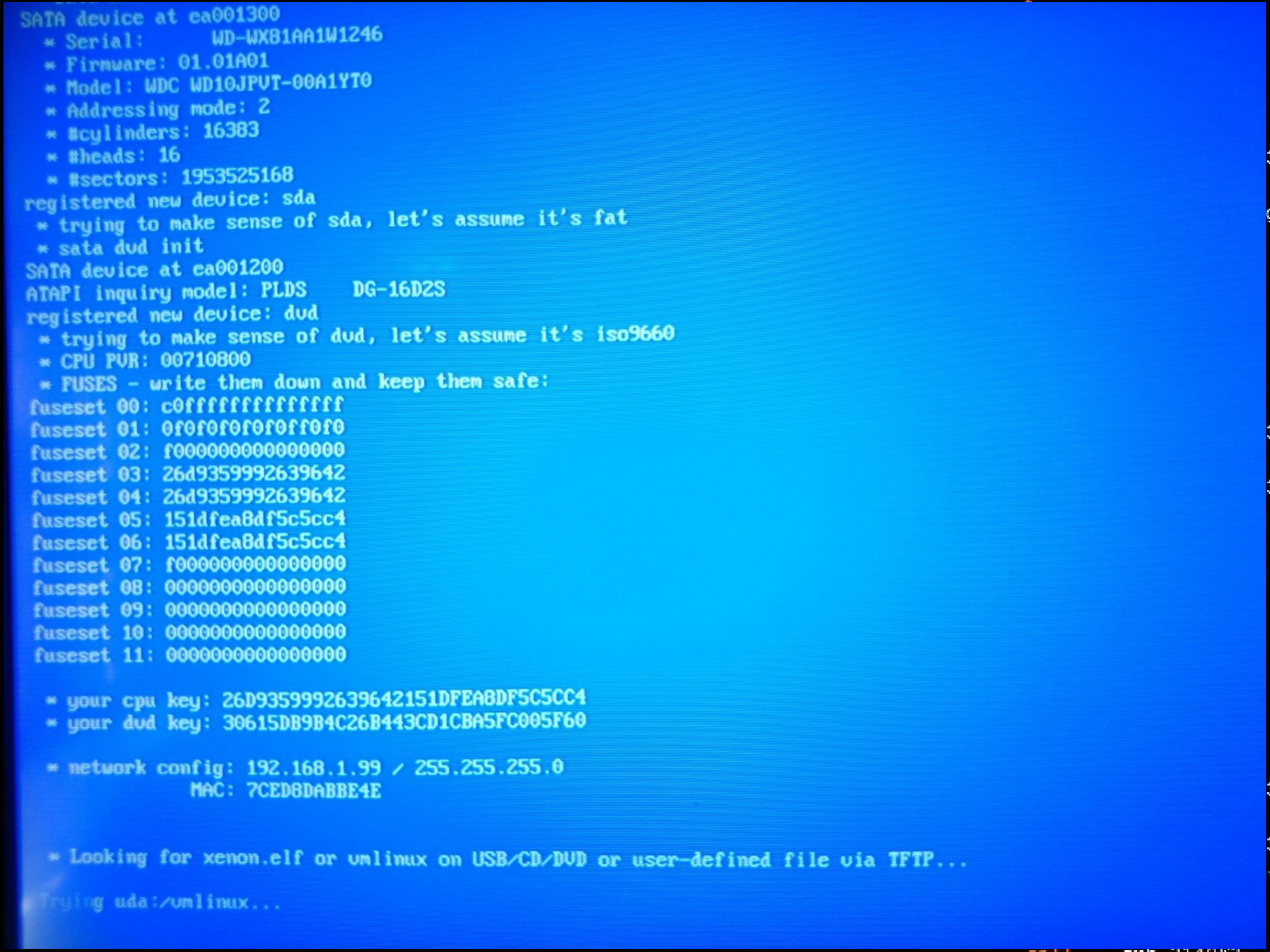


```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_70]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
push    esi
push    eax
        rg_0],
        486A
        ax
        loc_31306D
        ebp+arg_0]
        D0h
        rg_4]
        4623
        ax
        loc_31306D
        rg_0], esi
        loc_31308F
                        ; CODE XREF: sub_312FD8
                        ; sub_312FD8+55
        411B
                        ; CODE XREF: sub_312FD8
                        ; sub_312FD8+49
        40F3
        ax
        loc_31307
        40F3
        loc_31308C
                        ; CODE XREF: sub_312FD8
call    sub_3140F3
and     eax, 0FFFFh
or      eax, 80070000h
loc_31308C:             ; CODE XREF: sub_312FD8
mov     [ebp+var_4], eax
```

Game Over



```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_70]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
```

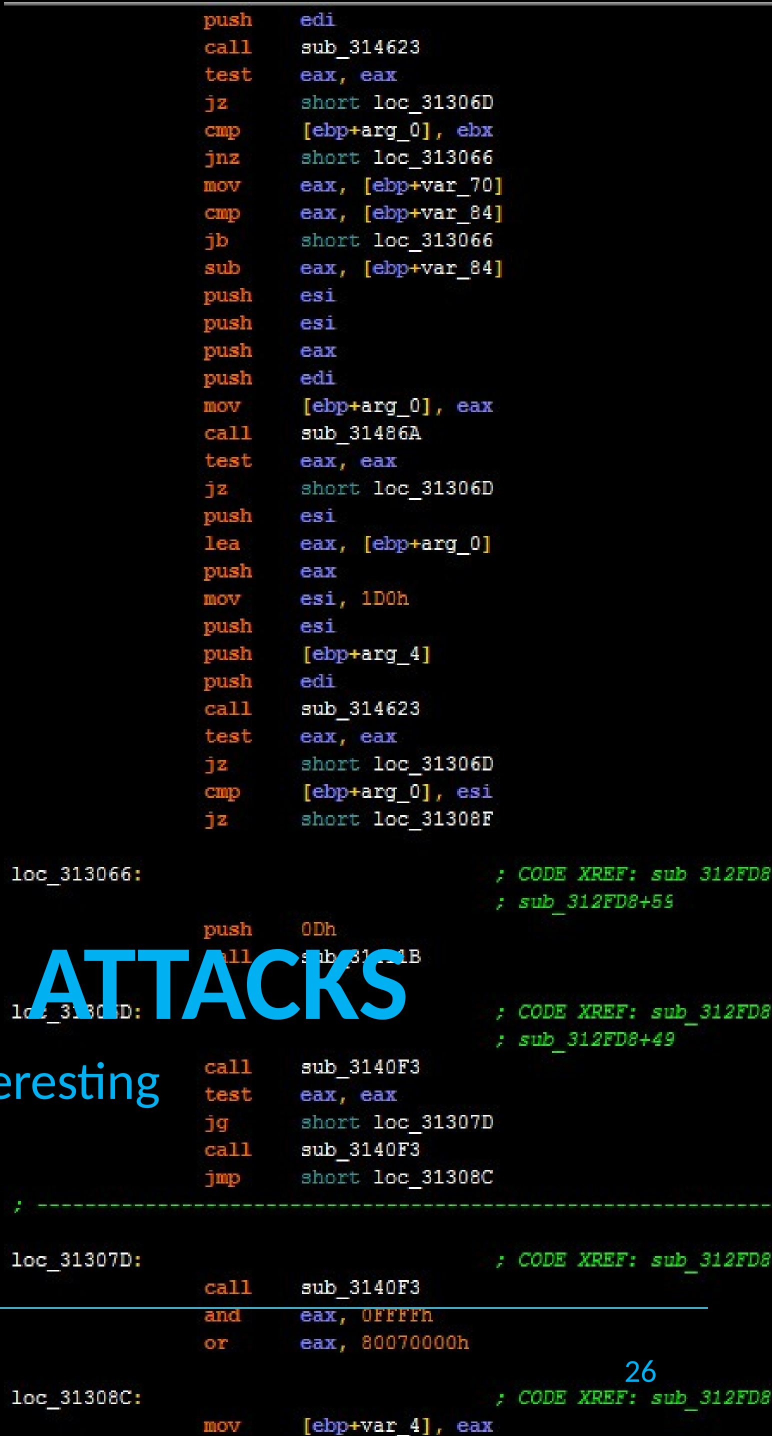


```
SATA device at ea001300
  * Serial:       WD-WXB1AA1W1246
  * Firmware: 01.01A01
  * Model: WDC WD10JPVT-00A1YT0
  * Addressing mode: 2
  * #cylinders: 16383
  * #heads: 16
  * #sectors: 1953525168
registered new device: sda
 * trying to make sense of sda, let's assume it's fat
 * sata dvd init
SATA device at ea001200
ATAPI inquiry model: PLDS    DG-16D2S
registered new device: dvd
 * trying to make sense of dvd, let's assume it's iso9660
 * CPU PVR: 00710800
 * FUSES - write them down and keep them safe:
fuseset 00: c0ffffffffffffff
fuseset 01: 0f0f0f0f0f0ff0f0
fuseset 02: f000000000000000
fuseset 03: 26d9359992639642
fuseset 04: 26d9359992639642
fuseset 05: 151dfea8df5c5cc4
fuseset 06: 151dfea8df5c5cc4
fuseset 07: f000000000000000
fuseset 08: 0000000000000000
fuseset 09: 0000000000000000
fuseset 10: 0000000000000000
fuseset 11: 0000000000000000

  * your cpu key: 26D9359992639642151DFEA8DF5C5CC4
  * your dvd key: 30615DB9B4C26B443CD1CBA5FC005F60

  * network config: 192.168.1.99 / 255.255.255.0
               MAC: 7CED8DABBE4E


  * Looking for xenon.elf or vmlinux on USB/CD/DVD or user-defined file via TFTP...

Trying uda:/vmlinux...
```

```
call    sub_3140F3
and     eax, 0FFFFh
or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
mov     [ebp+var_4], eax
```

XBOX 360 HARDWARE ATTACKS

Straying from binary exploitation, but still interesting



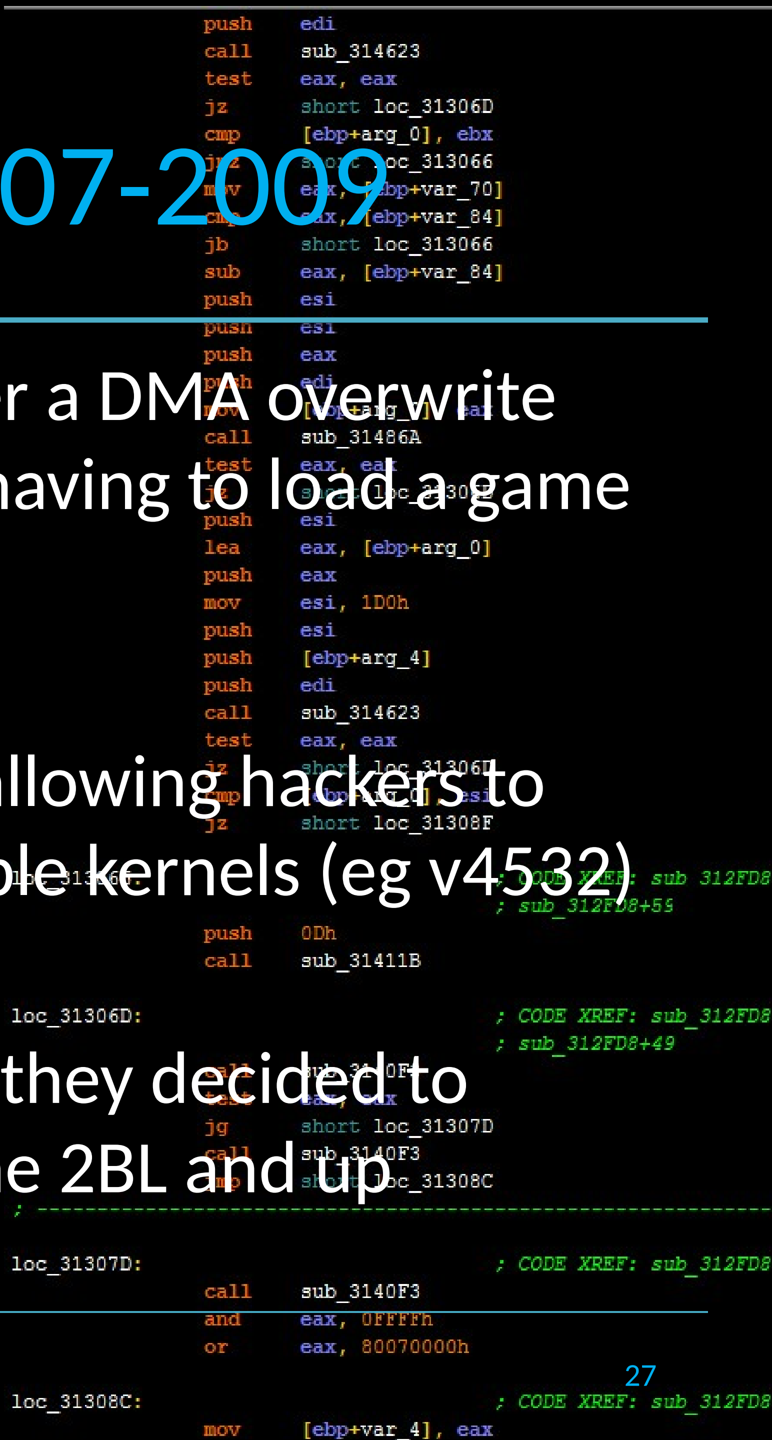
```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31[illegible]1B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

SMC / JTAG Hack – 2007-2009

- Uses the SMC and JTAG to trigger a DMA overwrite instantly at bootup rather than having to load a game such a King Kong

- Cat and mouse for a few years, allowing hackers to boot into downgraded, exploitable kernels (eg v4532)

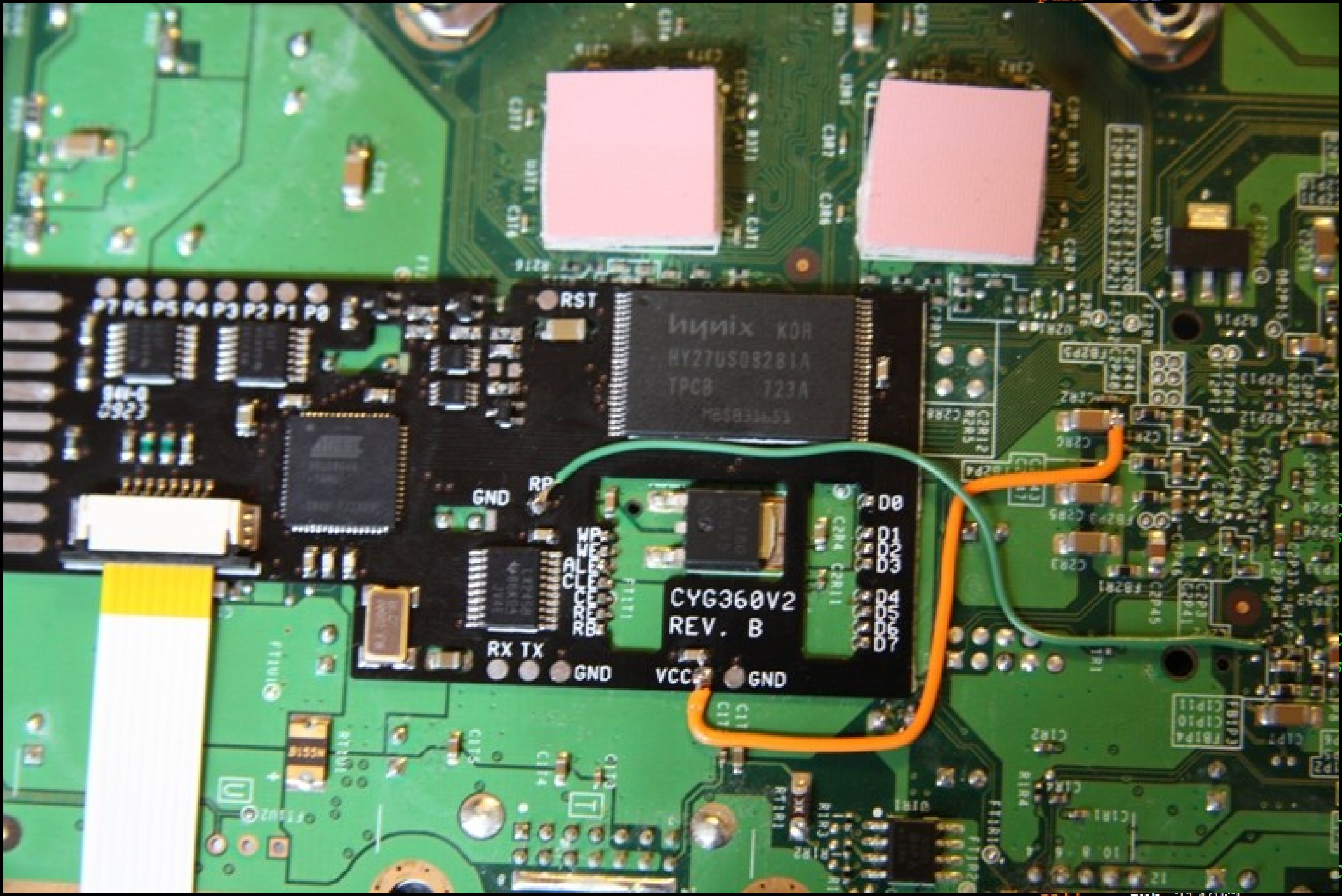
- Eventually Patched by MS when they decided to rework the boot process from the 2BL and up



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_3130[illegible]
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_31[illegible]0F[illegible]
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

SMC / JTAG Hack

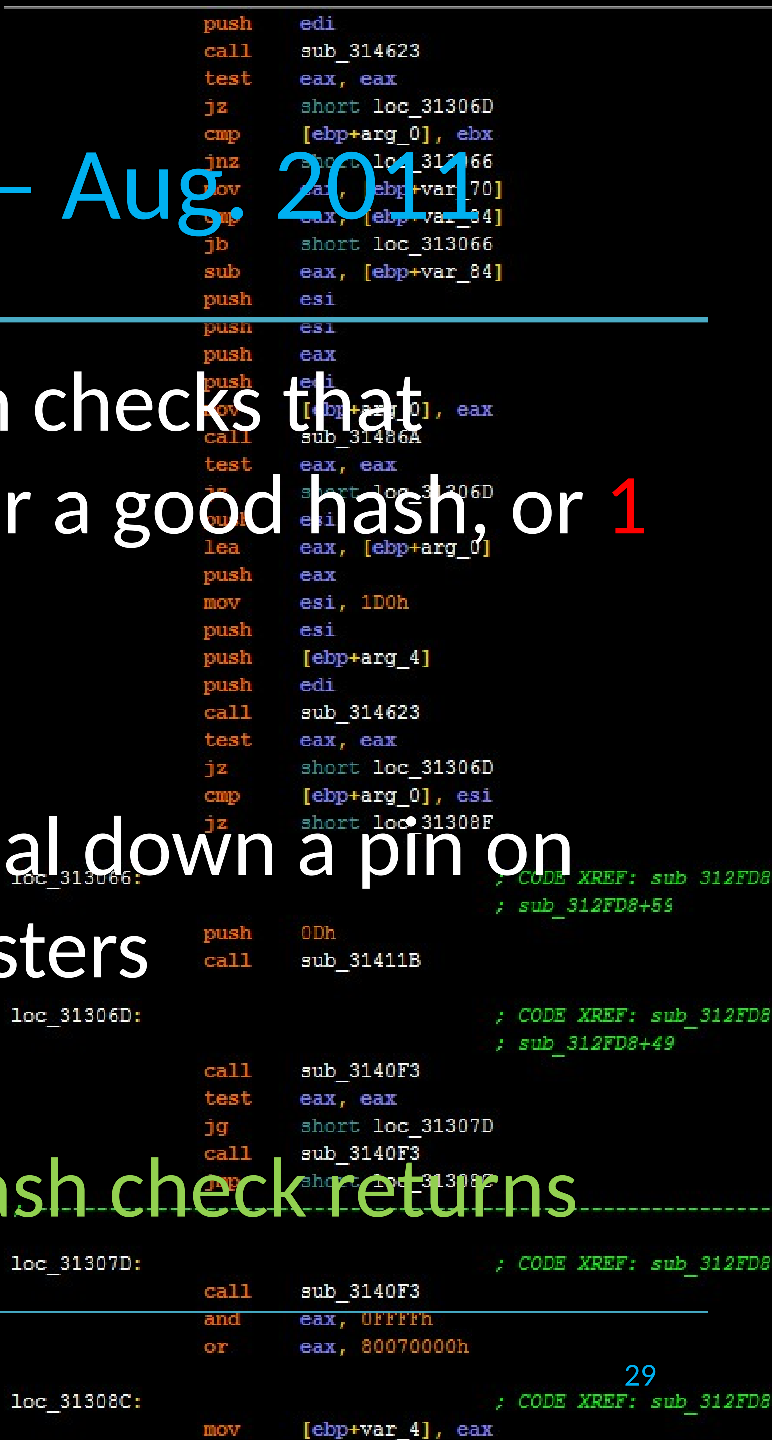
```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_70]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
push    esi
```



```
CODE XREF: sub_312FD8
sub_312FD8+55

CODE XREF: sub_312FD8
sub_312FD8+49

CODE XREF: sub_312FD8
call    sub_3140F3
and     eax, 0FFFFh
or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
mov     [ebp+var_4], eax
```

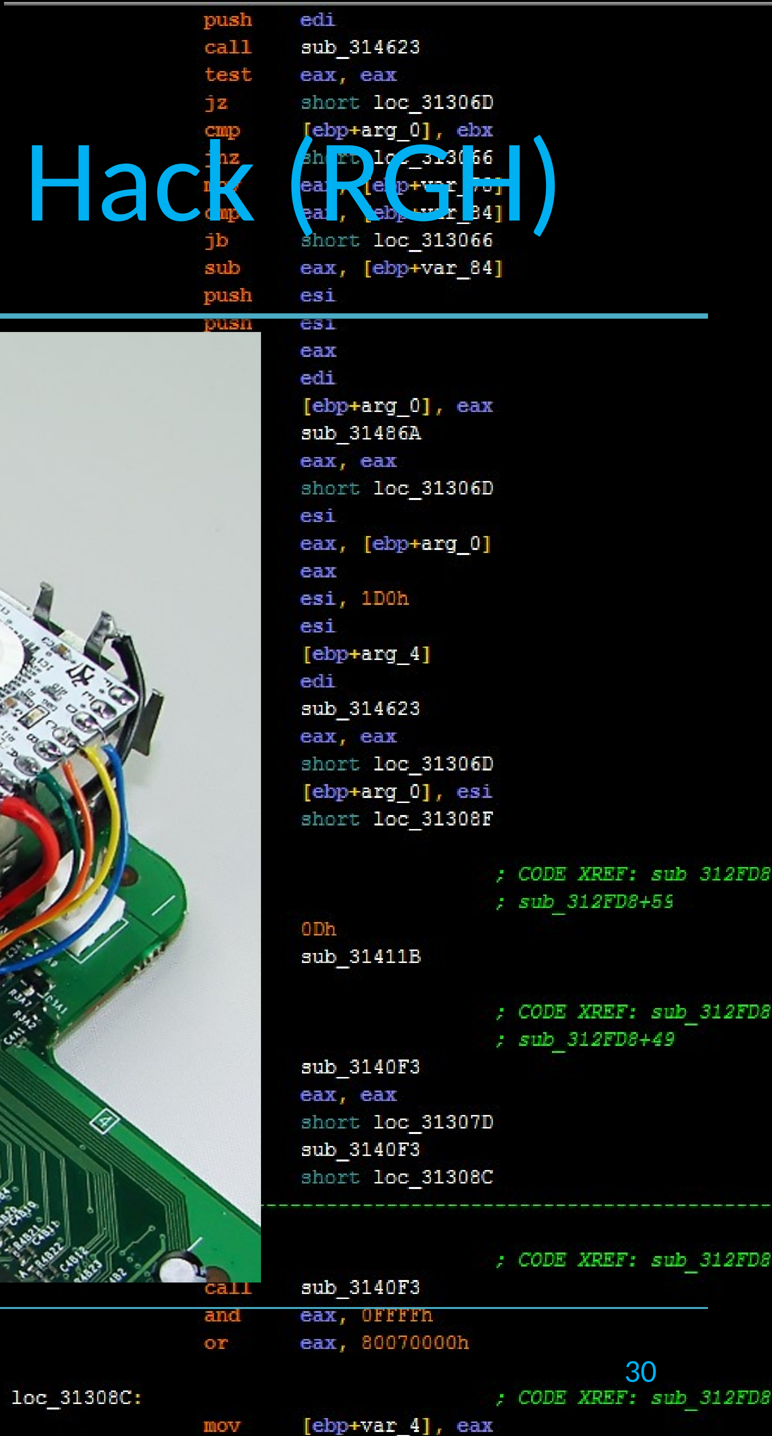
Reset Glitch Hack (RGH) – Aug. 2011

- In the 2bl there's some hash checks that expect a 0 to be returned for a good hash, or 1 for a hash mismatch (fail)
- Sending a specific reset signal down a pin on the CPU clears the CPU registers
- Reset the registers as the hash check returns

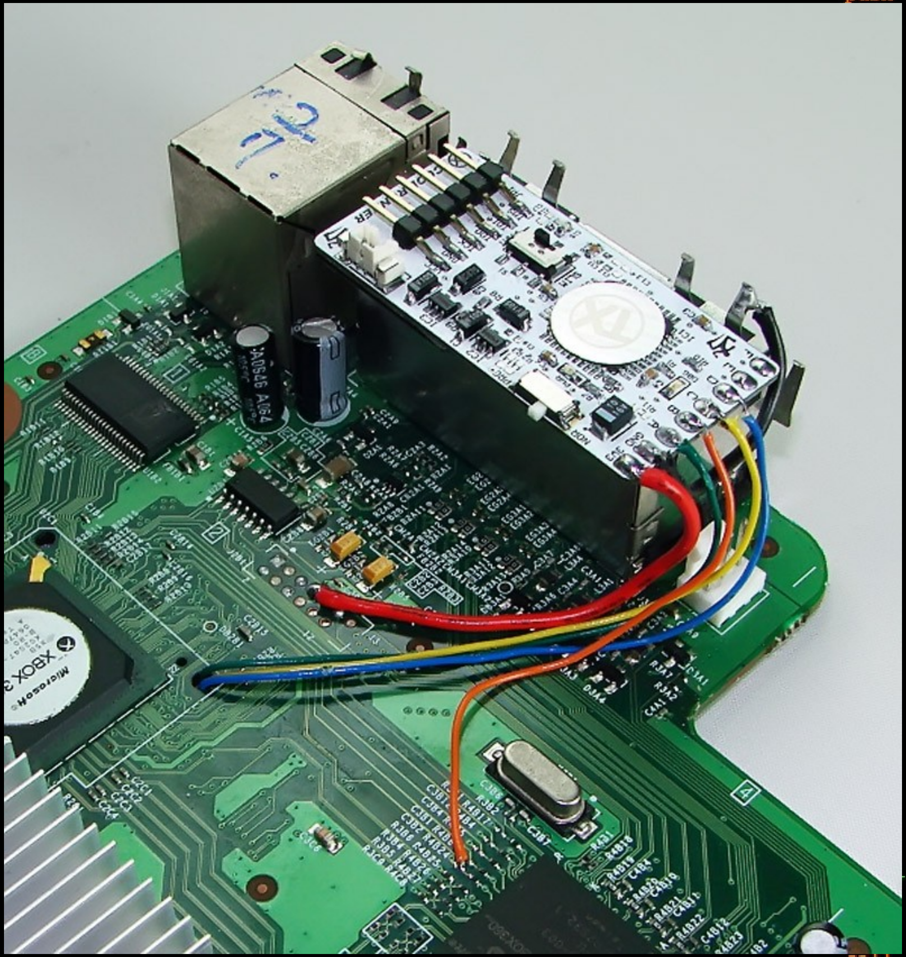


```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

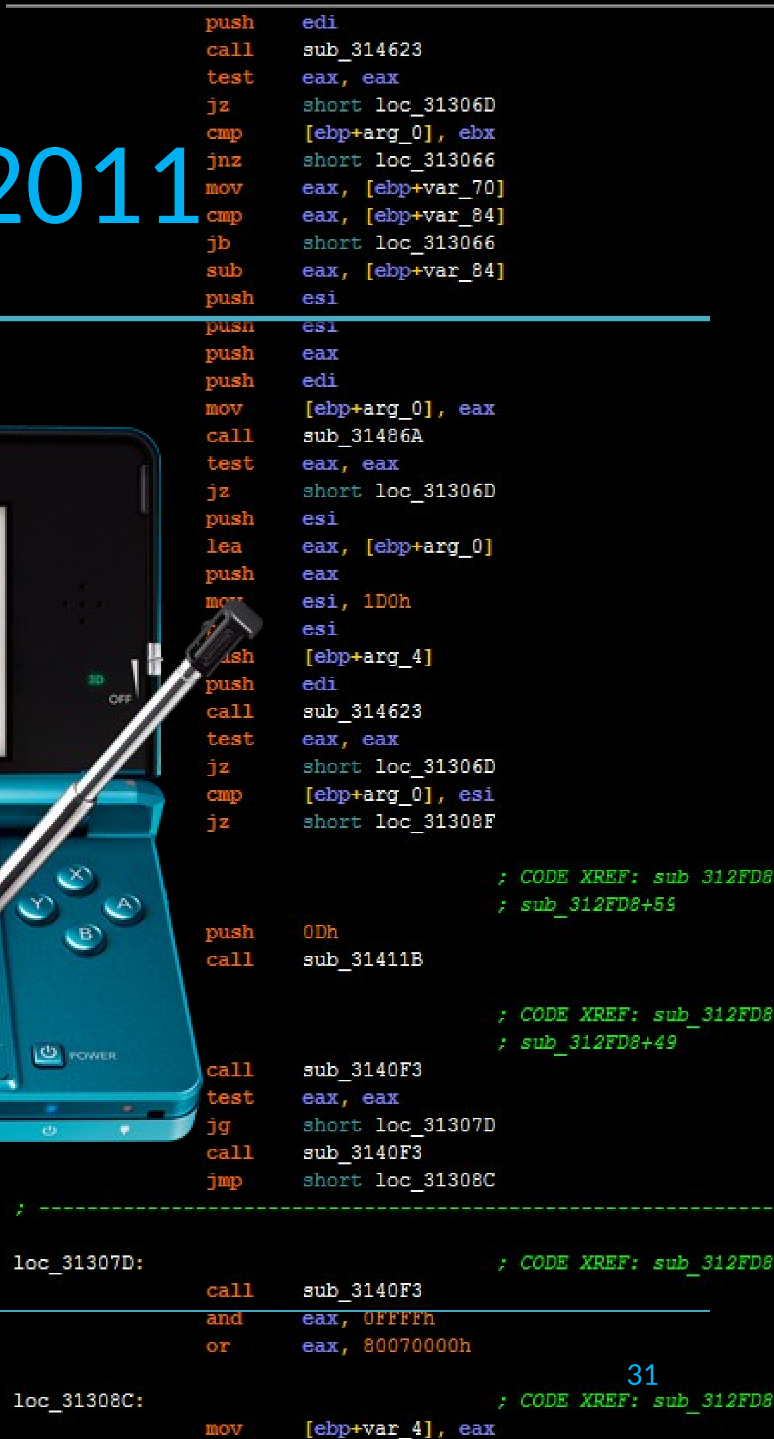
Xbox 360 Reset Glitch Hack (RGH)



```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_78]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
push    esi
        eax
        edi
        [ebp+arg_0], eax
        sub_31486A
        eax, eax
        short loc_31306D
        esi
        eax, [ebp+arg_0]
        eax
        esi, 1D0h
        esi
        [ebp+arg_4]
        edi
        sub_314623
        eax, eax
        short loc_31306D
        [ebp+arg_0], esi
        short loc_31308F

                              ; CODE XREF: sub_312FD8
                              ; sub_312FD8+55
        0Dh
        sub_31411B

                              ; CODE XREF: sub_312FD8
                              ; sub_312FD8+49
        sub_3140F3
        eax, eax
        short loc_31307D
        sub_3140F3
        short loc_31308C
---------------------------------------------------------

                              ; CODE XREF: sub_312FD8
call    sub_3140F3
and     eax, 0FFFFh
or      eax, 80070000h

loc_31308C:                   ; CODE XREF: sub_312FD8
mov     [ebp+var_4], eax
```



Nintendo 3DS – Feb. 2011

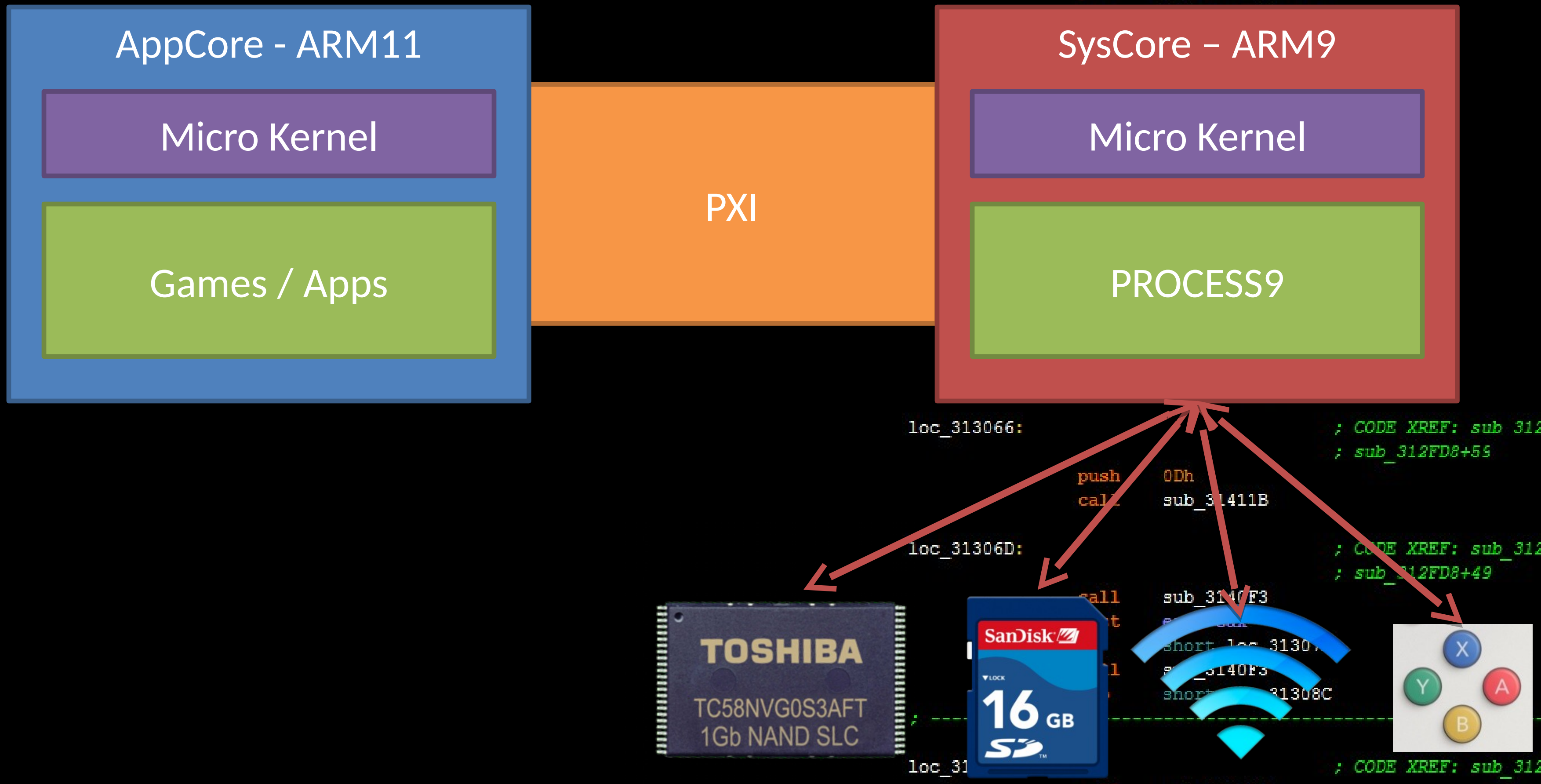

```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

                                        ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

                                        ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

Nintendo 3DS – Feb. 2011

- Security Perspective
  - Very tightly sealed bootrom, hardware disabled
  - Only runs signed code or executables
  - Hardware based keyscrambler for crypto keys
  - NX/DEP (Only on the ARM11 AppCore)
  - Runtime memory is not encrypted
  - No eFuses
  - No ASLR

```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

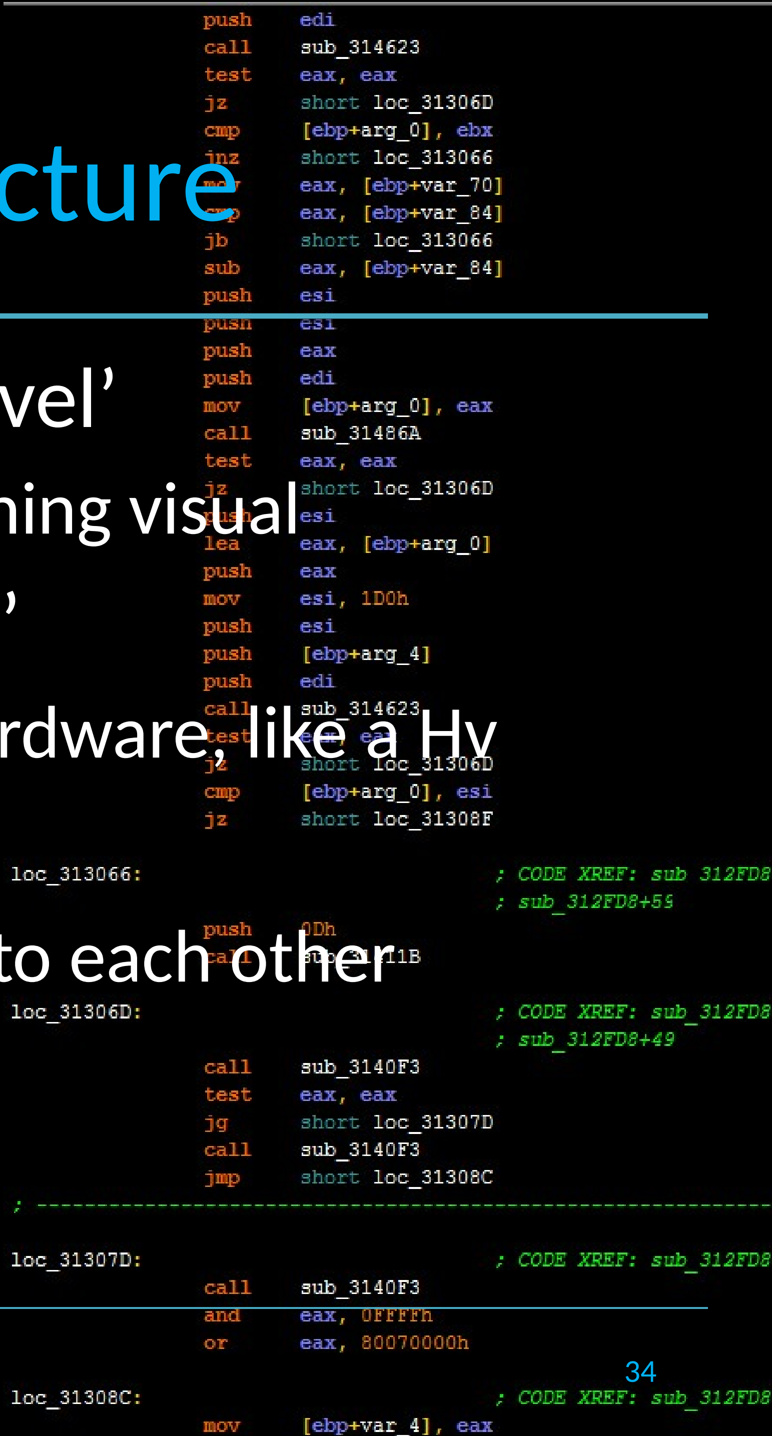
Nintendo 3DS Architecture



```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_70]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
push    esi
push    eax
push    edi

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
push    0Dh
call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
call    sub_3140F3

loc_31                                  ; CODE XREF: sub_312FD8
call    sub_3140F3
and     eax, 0FFFFh
or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
mov     [ebp+var_4], eax
```

Nintendo 3DS Architecture

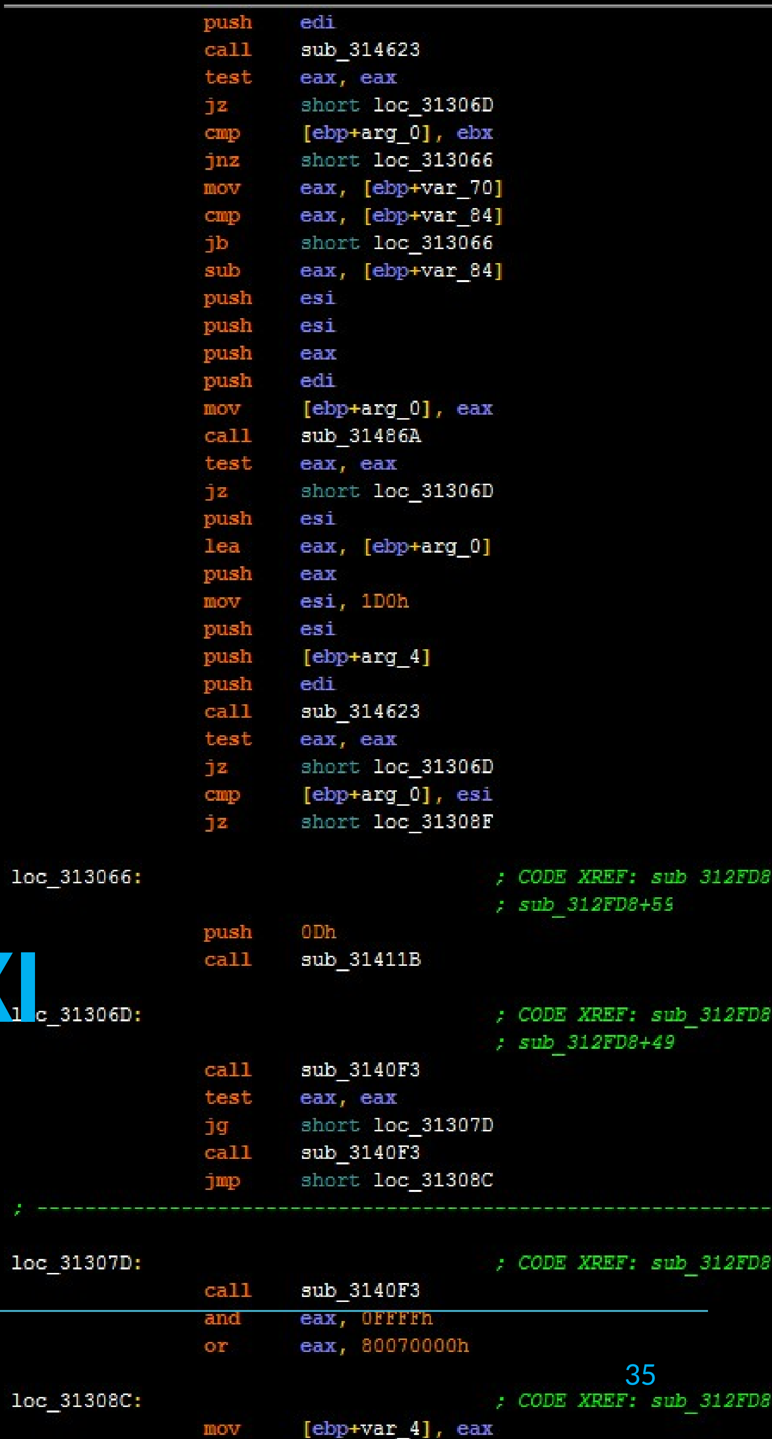
- AppCore (ARM11) – ‘high level’
  - Runs your games, apps, anything visual
- SysCore (ARM9) – ‘low level’
  - Crypto, system IO, talks to hardware, like a Hv
- PXI
  - Pipeline for the cores to talk to each other



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    [illegible]11B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

PWNING OVER THE PXI

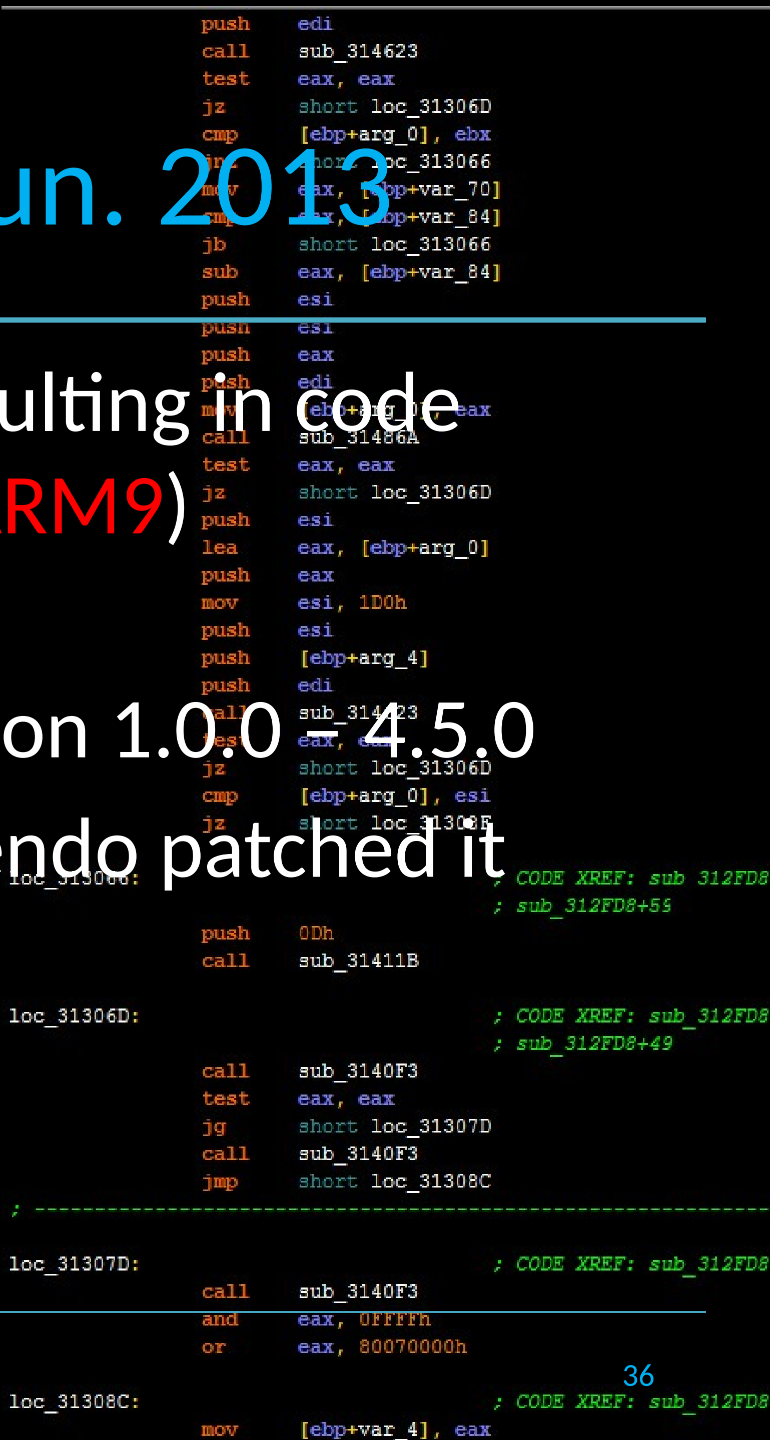
Owning the SysCore through the PXI



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

VerifyRsaSha256() – Jun. 2013

- Privilege escalation bug, resulting in code execution on the SysCore (ARM9)
  - Complete system control
- Present from firmware version 1.0.0 – 4.5.0
- Discovered only when Nintendo patched it

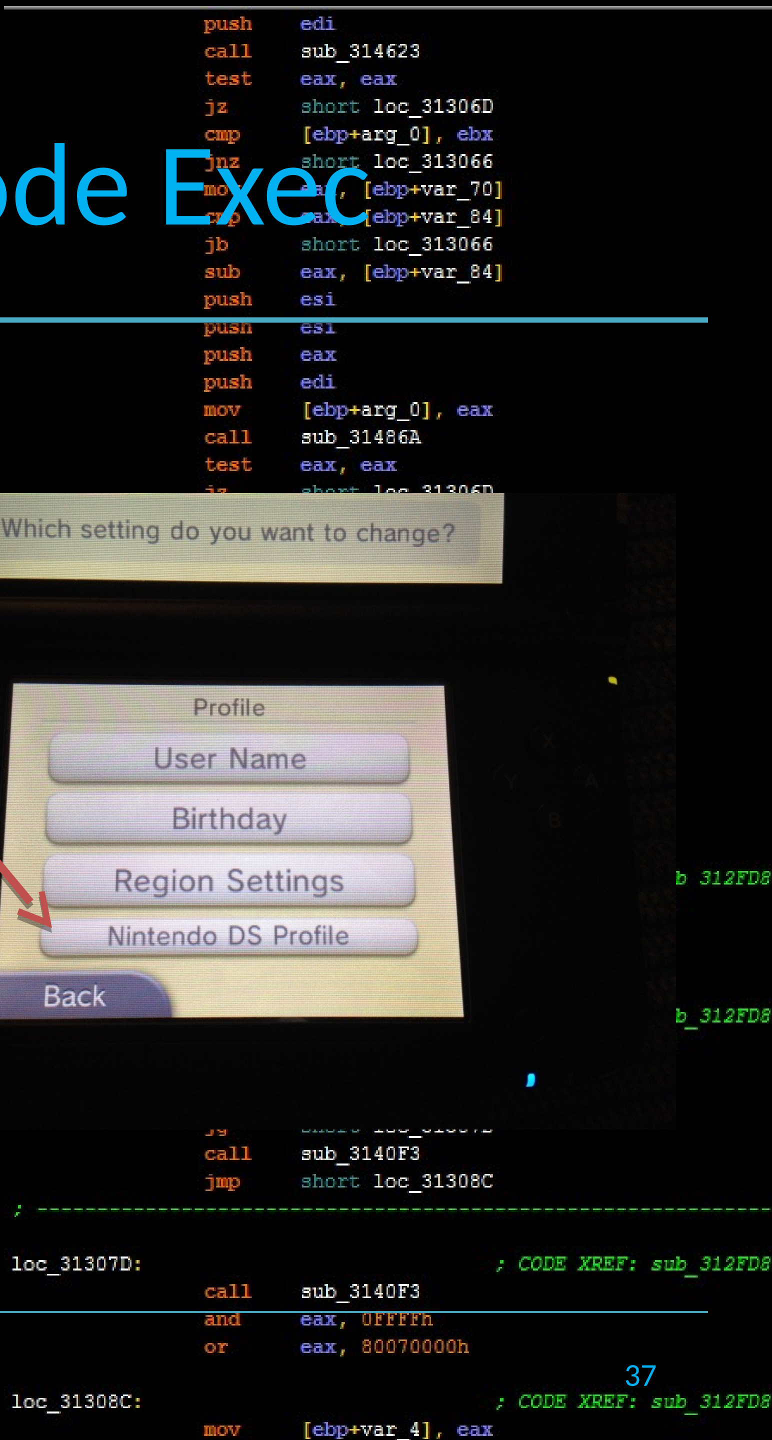


```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308E

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

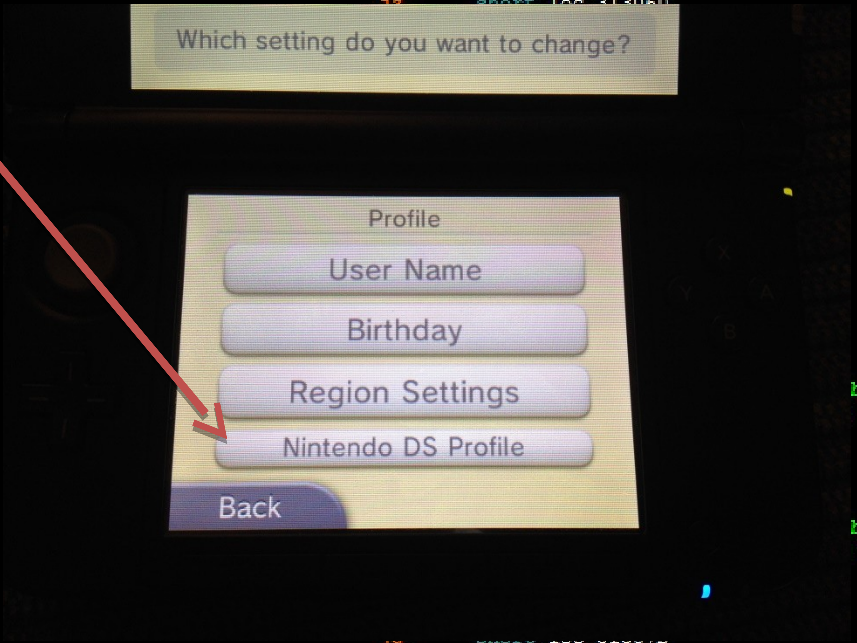
Stage One: ARM11 Code Exec

- A stack smash exists in the DS Profile fields in the native settings application on all 3DS's at the time. No need for any games!

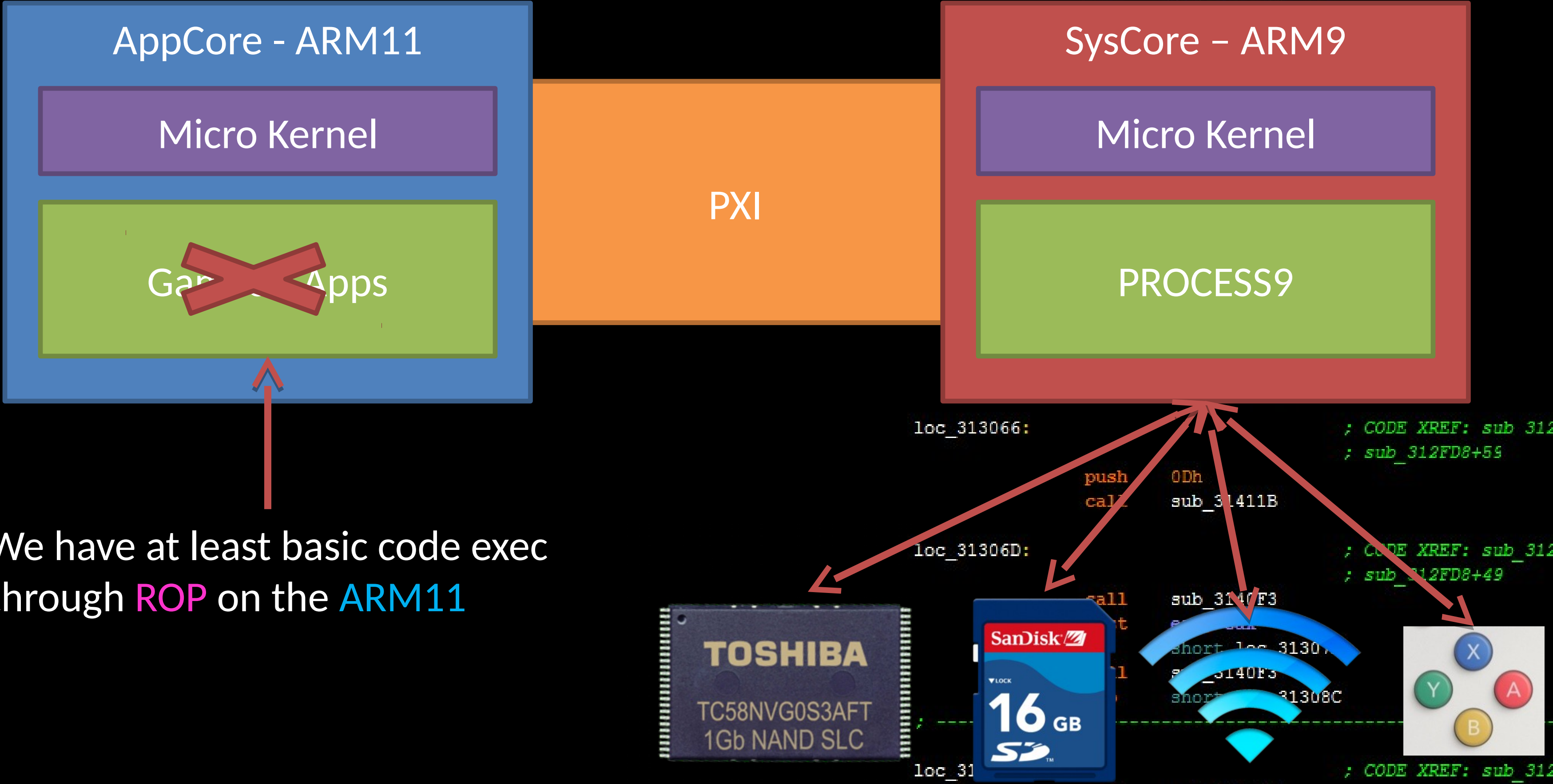
- This is a straight stack smash that will get us control, but there is DEP on the ARM11 so you must ROP



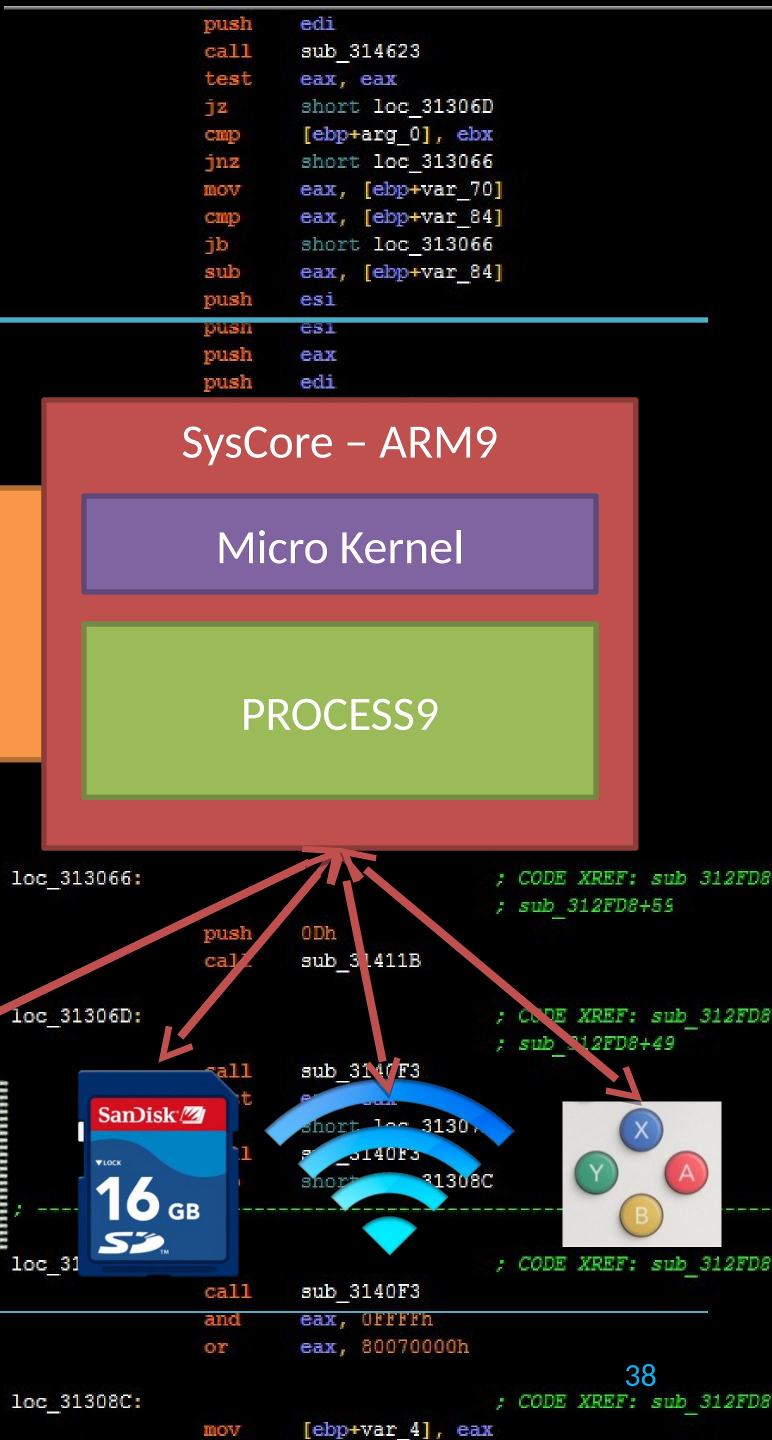
```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax

                                                                        b 312FD8

                                                                        b_312FD8

                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------------------

loc_31307D:                                     ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                                     ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```



State of Control

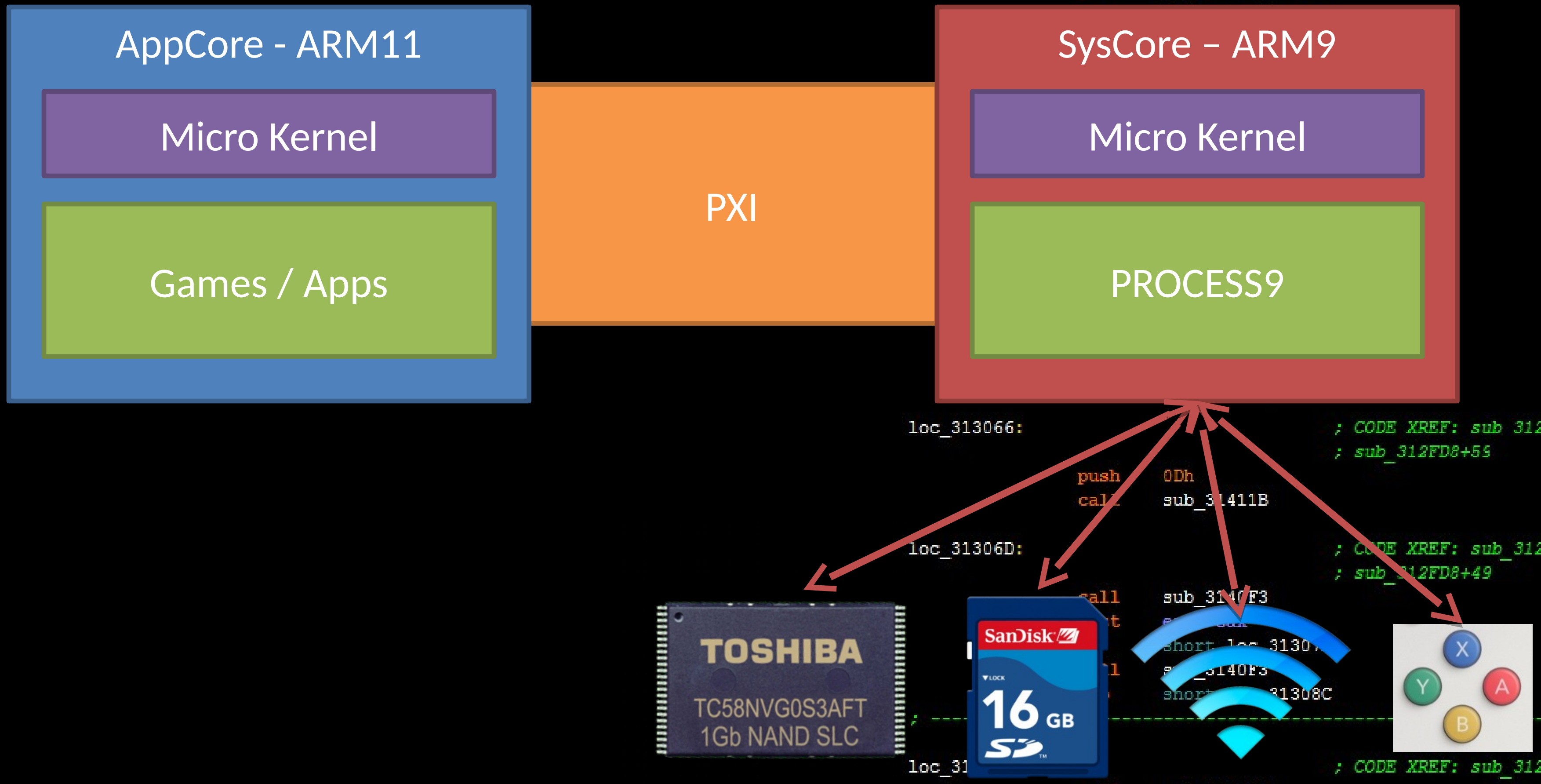


We have at least basic code exec through ROP on the ARM11



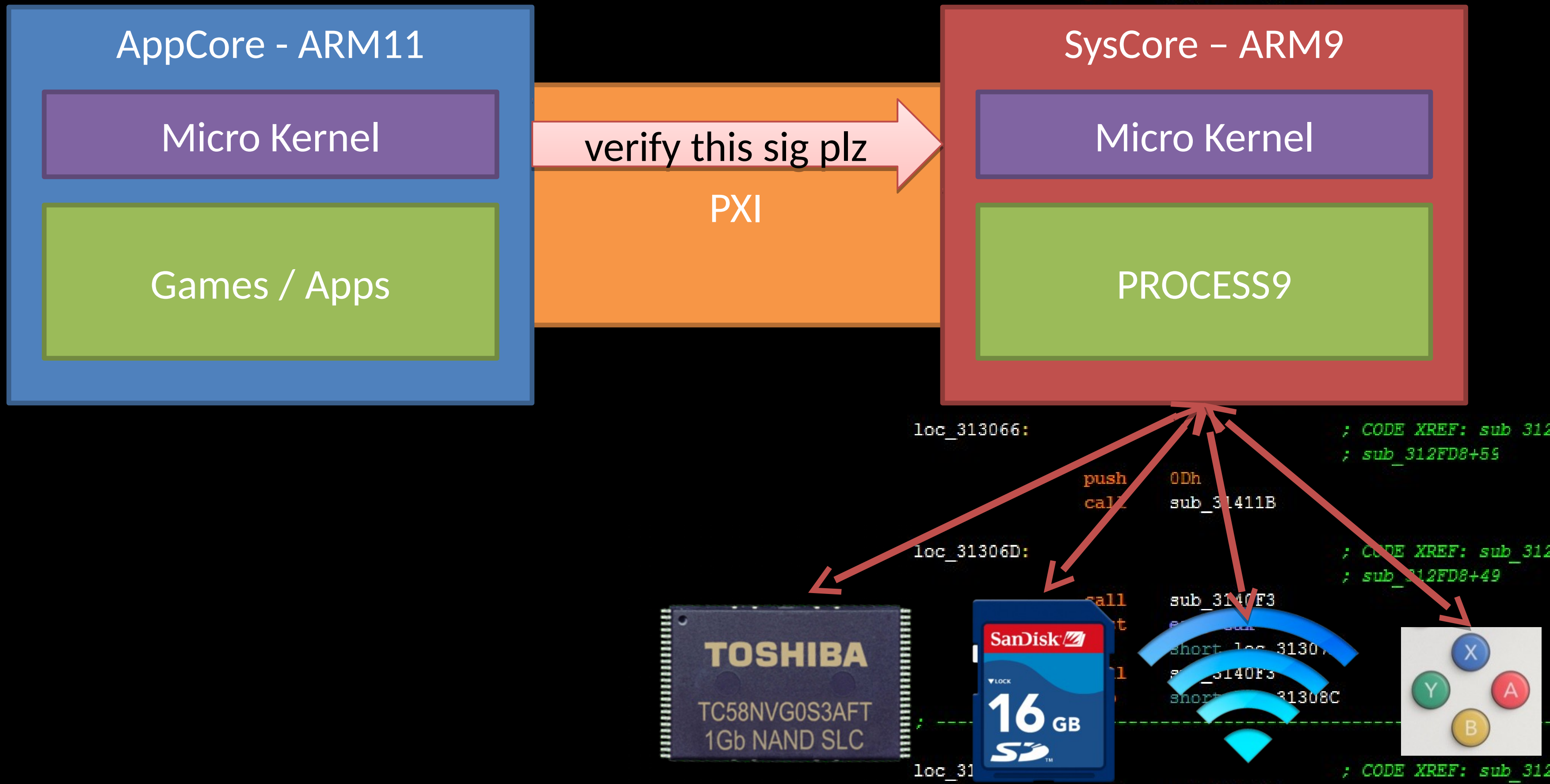
```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3

loc_31[illegible]                       ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

Normal PXI Requests



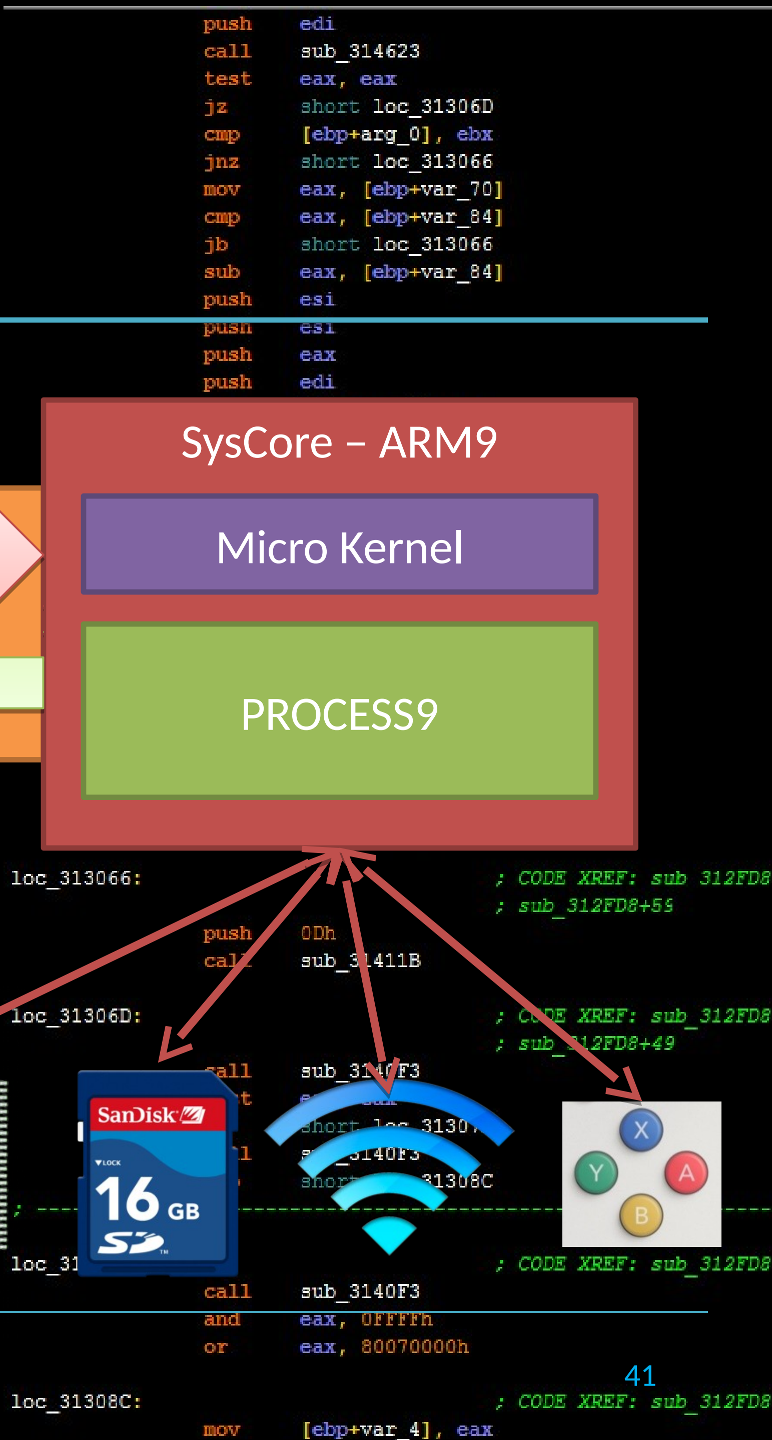
Normal PXI Requests

```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_70]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
push    esi
push    eax
push    edi
```

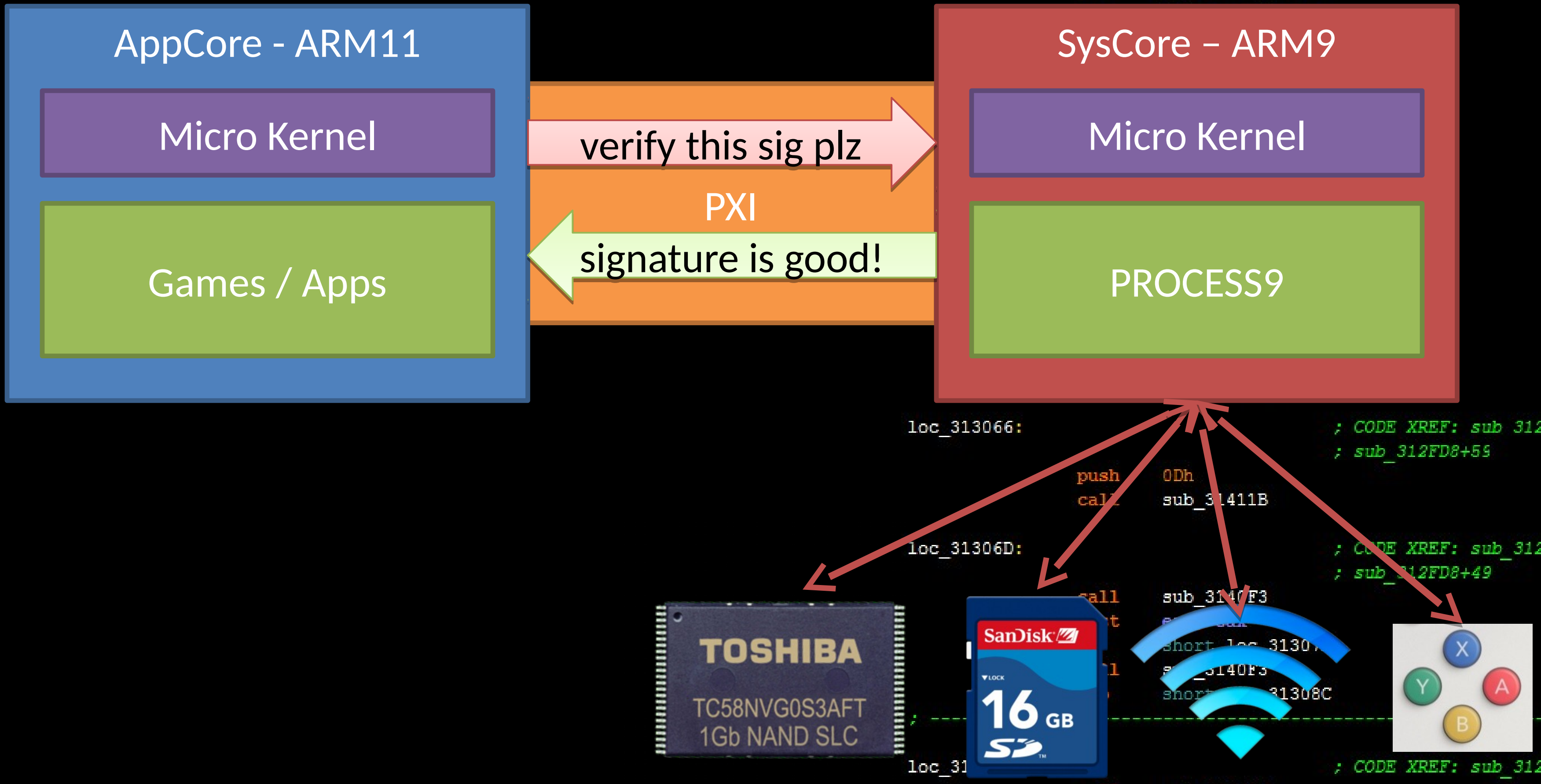


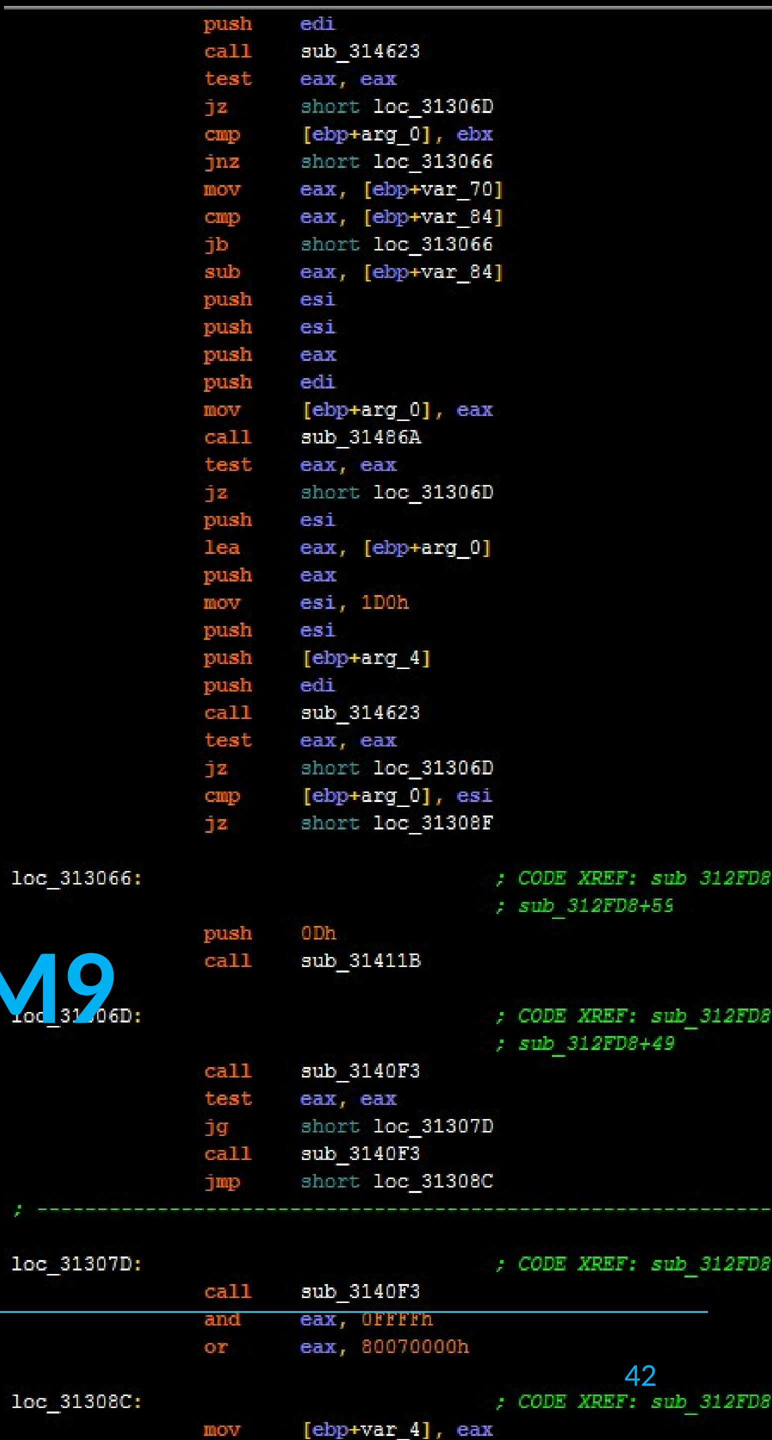
```
loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3

loc_31                                  ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

Normal PXI Requests



```
        push    edi
        call    sub_314623
        test    eax, eax
        jz      short loc_31306D
        cmp     [ebp+arg_0], ebx
        jnz     short loc_313066
        mov     eax, [ebp+var_70]
        cmp     eax, [ebp+var_84]
        jb      short loc_313066
        sub     eax, [ebp+var_84]
        push    esi
        push    esi
        push    eax
        push    edi

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
        push    0Dh

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49

loc_31                                  ; CODE XREF: sub_312FD8
        call    sub_3140F3
        and     eax, 0FFFFh
        or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
        mov     [ebp+var_4], eax
```

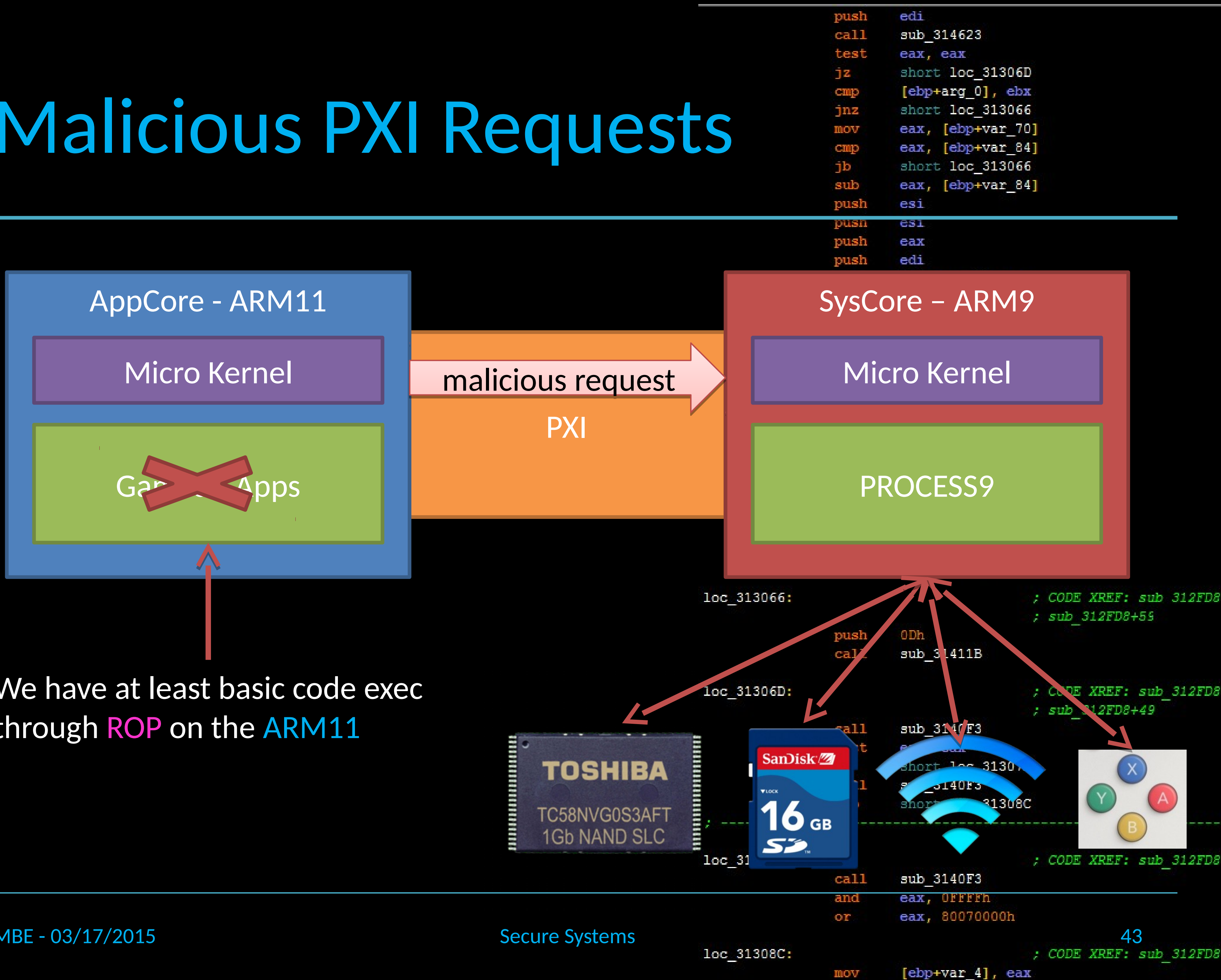




```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

TAKING OVER THE ARM9

Malicious PXI Requests

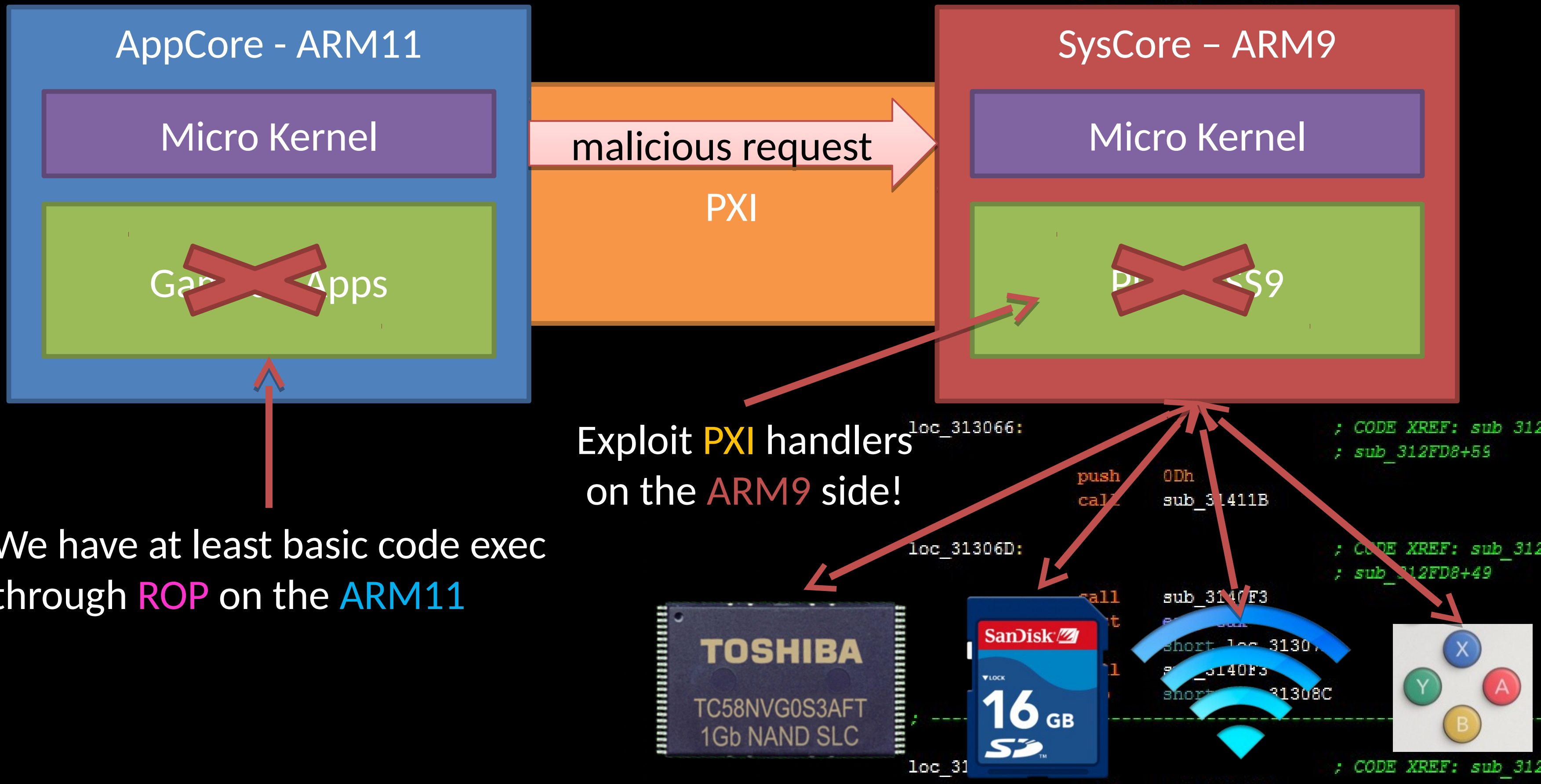


```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3

                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

We have at least basic code exec through ROP on the ARM11

Malicious PXI Requests

```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_70]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
push    esi
push    eax
push    edi
```



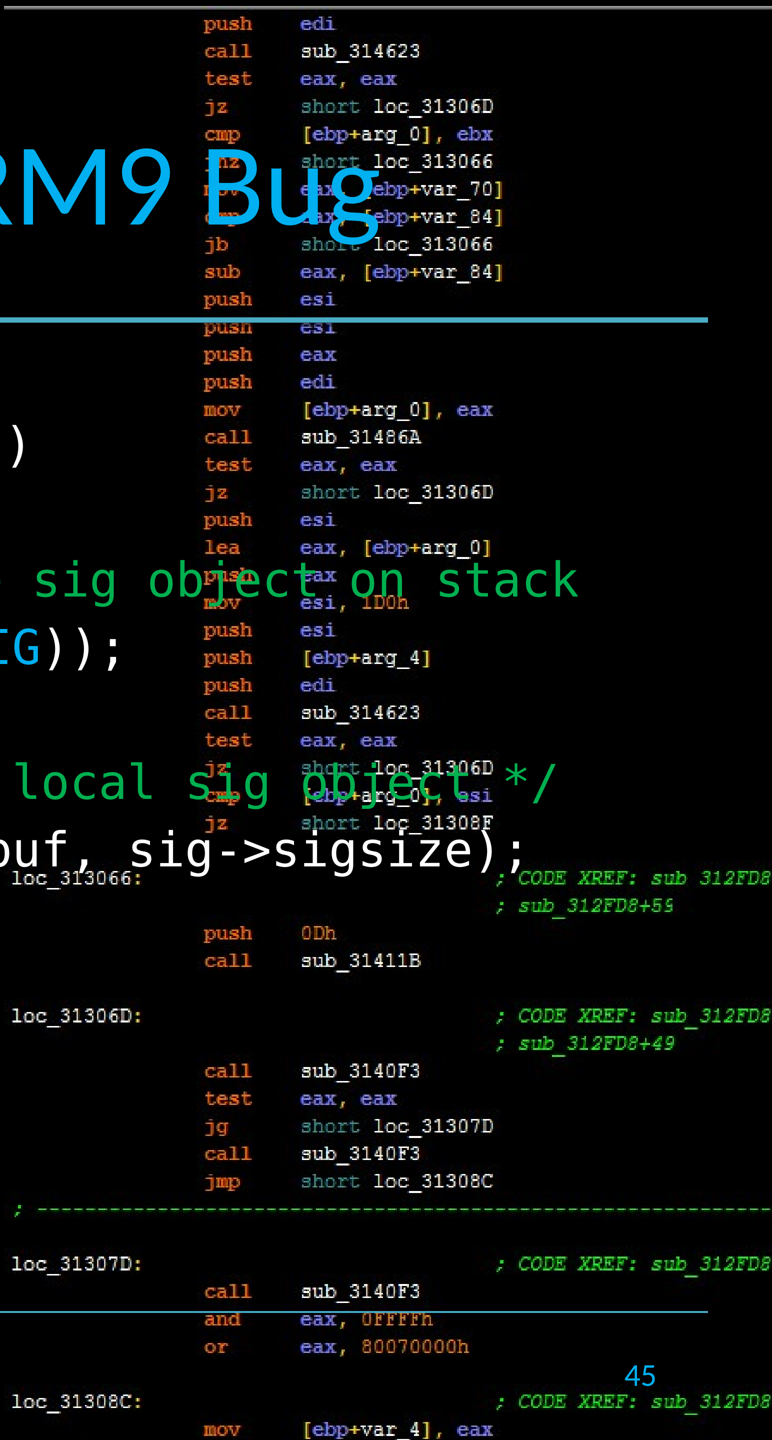
Exploit PXI handlers
on the ARM9 side!

We have at least basic code exec
through ROP on the ARM11

```
loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
push    0Dh
call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
call    sub_3140F3

loc_31                                  ; CODE XREF: sub_312FD8
call    sub_3140F3
and     eax, 0FFFFh
or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
mov     [ebp+var_4], eax
```

Pseudocode of the ARM9 Bug

```
int ps_VerifyRsaSha256(RSA_SIG * sig)
{
    RSA_SIG localsig;   // 0x208 byte sig object on stack
    memset(localsig, 0, sizeof(RSA_SIG));

    /* copy the RSA signature into a local sig object */
    memcpy(localsig.sigbuf, sig->sigbuf, sig->sigsize);

    ...

    return result;
}
```

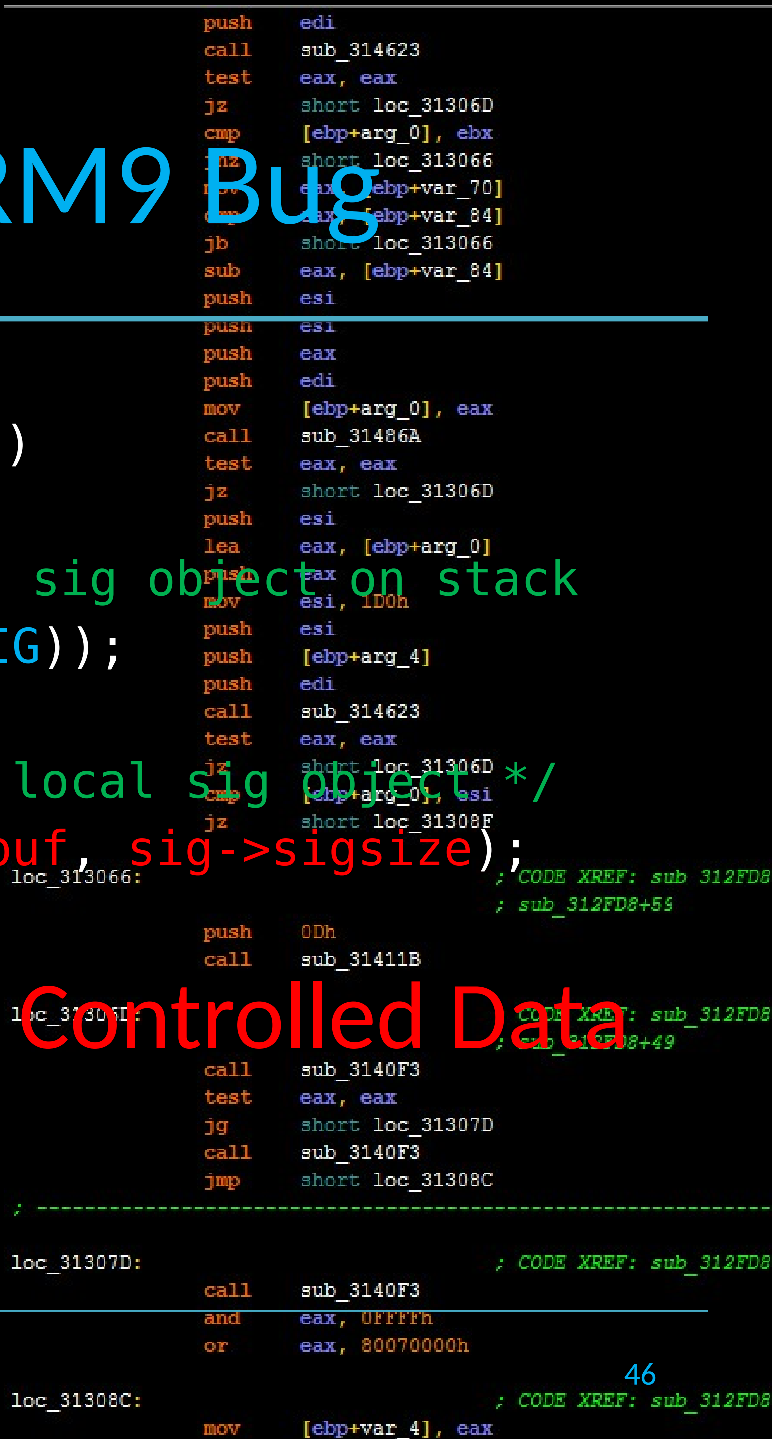


```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+5
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

Pseudocode of the ARM9 Bug

```
int ps_VerifyRsaSha256(RSA_SIG * sig)
{
    RSA_SIG localsig;   // 0x208 byte sig object on stack
    memset(localsig, 0, sizeof(RSA_SIG));

    /* copy the RSA signature into a local sig object */
    memcpy(localsig.sigbuf, sig->sigbuf, sig->sigsize);

    ...

    return result;
}
```

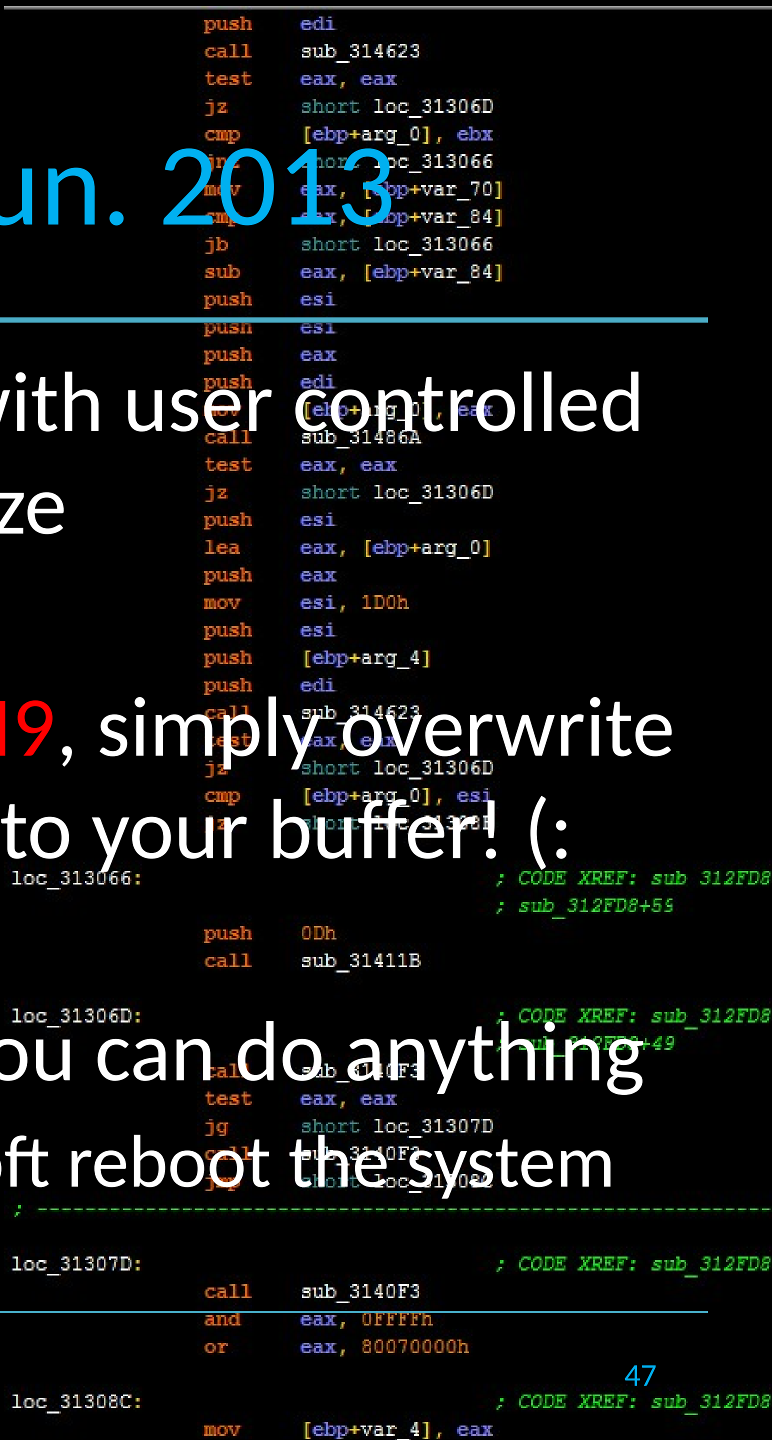
Attacker Controlled Data



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F
loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B
loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

VerifyRsaSha256() – Jun. 2013

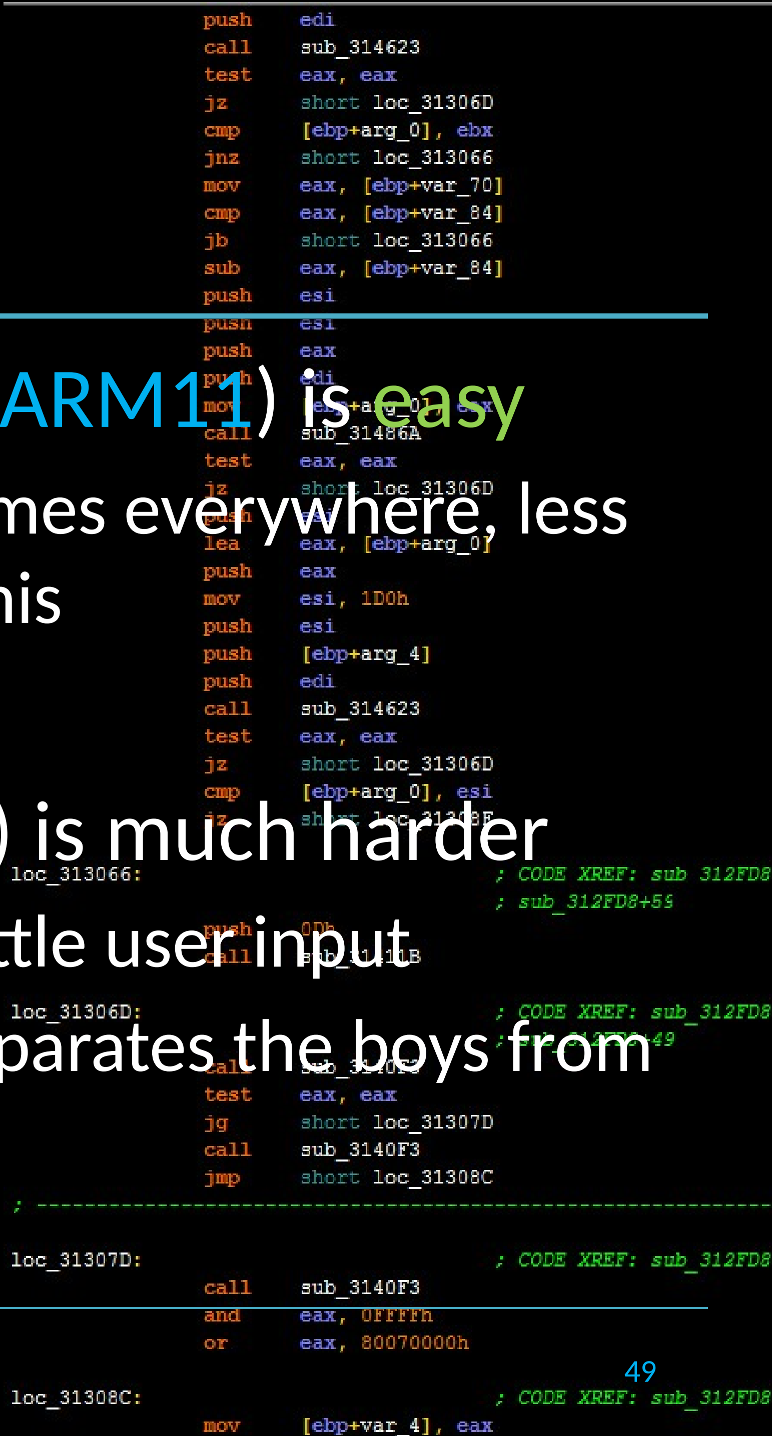
- Bug is basically a memcpy with user controlled data, and a user specified size
- No DEP or ASLR on the ARM9, simply overwrite return address and jump onto your buffer! (:
- With control of the ARM9 you can do anything
  - Load a custom firmware & soft reboot the system



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308[illegible]

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+59
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]




                                 g_0], eax
                                 36A
                                 t
                                 oc_31306D

                                 op+arg_0]

                                 0h

                                 g_4]

                                 523
                                 t
                                 oc_31306D
                                 g_0], esi
                                 oc_31308F

                                          ; CODE XREF: sub_312FD8
                                          ; sub_312FD8+55

                                 11B

                                          ; CODE XREF: sub_312FD8
                                          ; sub_312FD8+49
                                 0F3
                                 t
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                               ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                               ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

Owning the 3DS



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], esx
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub 312FD8
                                        ; sub_312FD8+59

                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

- Code exec on the AppCore (ARM11) is easy
  - Tons of crappy vulnerable games everywhere, less exciting exploits exist to do this

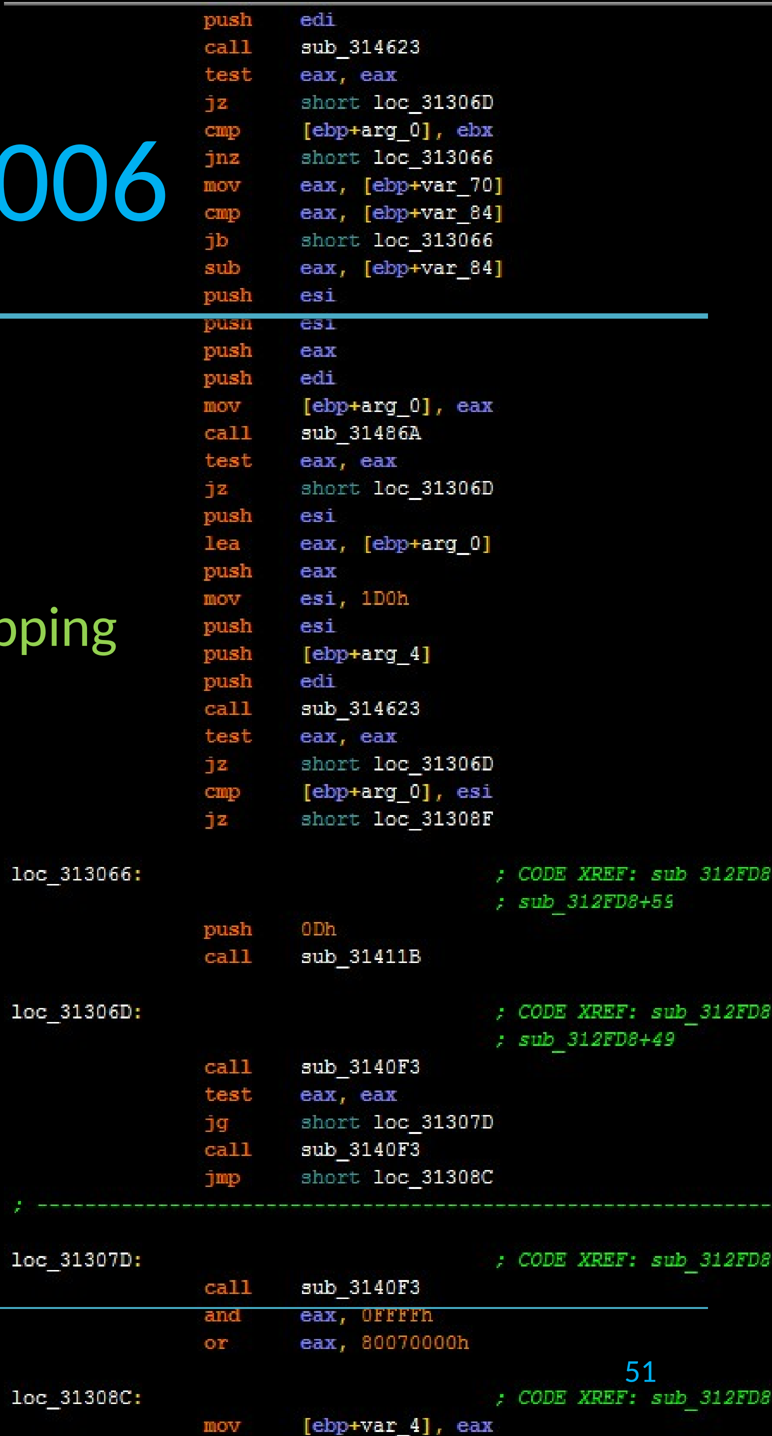
- Owning the SysCore (ARM9) is much harder
  - Limited attack surface with little user input
  - Owning the ARM9 is what separates the boys from the men

PlayStation 3 – Nov. 2006

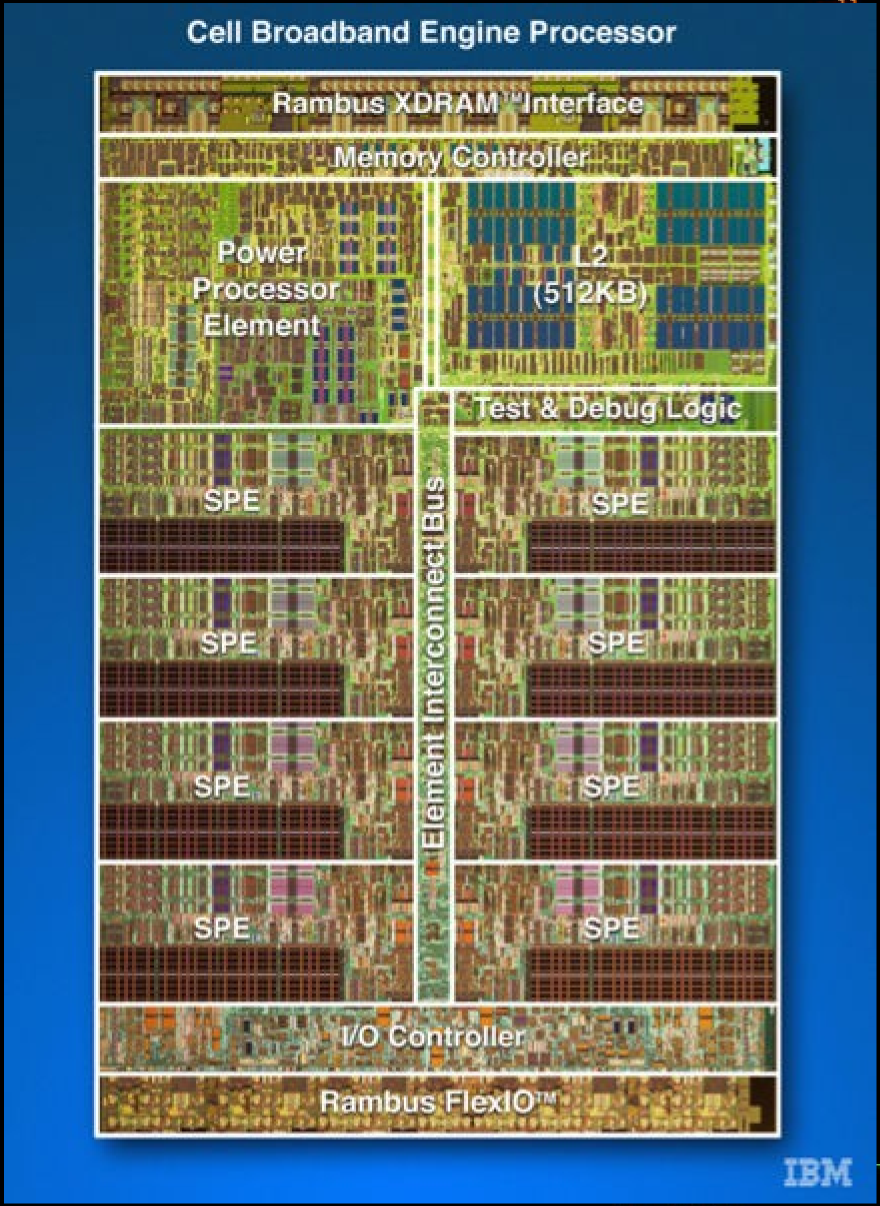
```
        push    edi
        call    sub_314623
        test    eax, eax
        jz      short loc_31306D
        cmp     [ebp+arg_0], ebx
        jnz     short loc_313066
        mov     eax, [ebp+var_70]
        cmp     eax, [ebp+var_84]
        jb      short loc_313066
        sub     eax, [ebp+var_84]
        push    esi
        push    esi
        push    eax
        push    edi
        mov     [ebp+arg_0], eax
        call    sub_31486A
        test    eax, eax
        jz      short loc_31306D
        push    esi
        lea     eax, [ebp+arg_0]
        push    eax
        mov     esi, 1D0h
        push    esi
        push    [ebp+arg_4]
        push    edi
        call    sub_314623
        test    eax, eax
        jz      short loc_31306D
        cmp     [ebp+arg_0], esi
        jz      short loc_31308F

3066:                                   ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
        push    0Dh
        call    sub_31411B

306D:                                   ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
        call    sub_3140F3
        test    eax, eax
        jg      short loc_31307D
        call    sub_3140F3
        jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
        call    sub_3140F3
        and     eax, 0FFFFh
        or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
        mov     [ebp+var_4], eax
```

PlayStation 3 – Nov. 2006

- Security Perspective
  - FreeBSD Based OS
  - Only runs signed code or executables
  - Rigorous chain of trust, secure bootstrapping
  - Cell Architecture
    - Isolates cores from each other, HV
    - Dedicated System / Security Cell
  - Encrypted runtime memory
  - Encrypted HDD
  - eFuses
  - NX/DEP
  - No ASLR

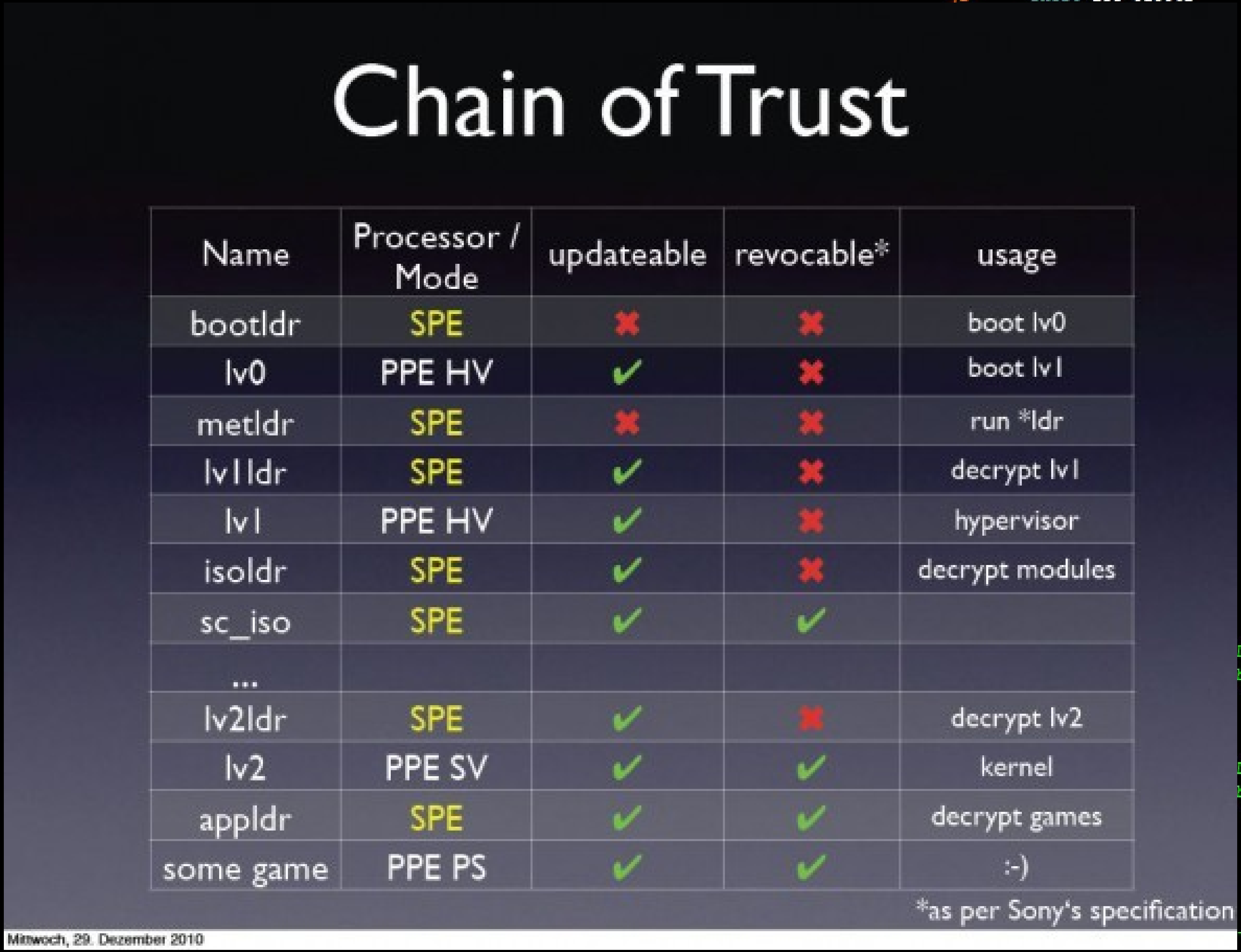


```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```



```
                push    edi
                        sub_314623
                        eax, eax
                        short loc_31306D
                        [ebp+arg_0], ebx
                        short loc_313066
                        eax, [ebp+var_70]
                        eax, [ebp+var_84]
                        short loc_313066
                        eax, [ebp+var_84]
                        esi
                        esi
                        eax
                        edi
                        [ebp+arg_0], eax
                        sub_31486A
                        eax, eax
                        short loc_31306D
                        esi
                        eax, [ebp+arg_0]
                        eax
                        esi, 1D0h
                        esi
                        [ebp+arg_4]
                        edi
                        sub_314623
                        eax, eax
                        short loc_31306D
                        [ebp+arg_0], esi
                        short loc_31308F

                                                ; CODE XREF: sub_312FD8
                                                ; sub_312FD8+55
                        0Dh
                        sub_31411B

                                                ; CODE XREF: sub_312FD8
                                                ; sub_312FD8+49
                        sub_3140F3
                        eax, eax
                        short loc_31307D
                        sub_3140F3
                        short loc_31308C
                        ---------------------------------------------

loc_31307D:                                     ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                                     ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

```
push    edi
call    sub_314623
test    eax, eax
jz      short loc 31306D
```



Chain of Trust

Name	Processor / Mode	updateable	revocable*	usage
bootldr	SPE	✗	✗	boot lv0
lv0	PPE HV	✓	✗	boot lv1
metldr	SPE	✗	✗	run *ldr
lv1ldr	SPE	✓	✗	decrypt lv1
lv1	PPE HV	✓	✗	hypervisor
isoldr	SPE	✓	✗	decrypt modules
sc_iso	SPE	✓	✓	
...				
lv2ldr	SPE	✓	✗	decrypt lv2
lv2	PPE SV	✓	✓	kernel
appldr	SPE	✓	✓	decrypt games
some game	PPE PS	✓	✓	:-)

*as per Sony's specification

Mittwoch, 29. Dezember 2010

```
DE XREF: sub_312FD8
b_312FD8+55

DE XREF: sub_312FD8
b_312FD8+49

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

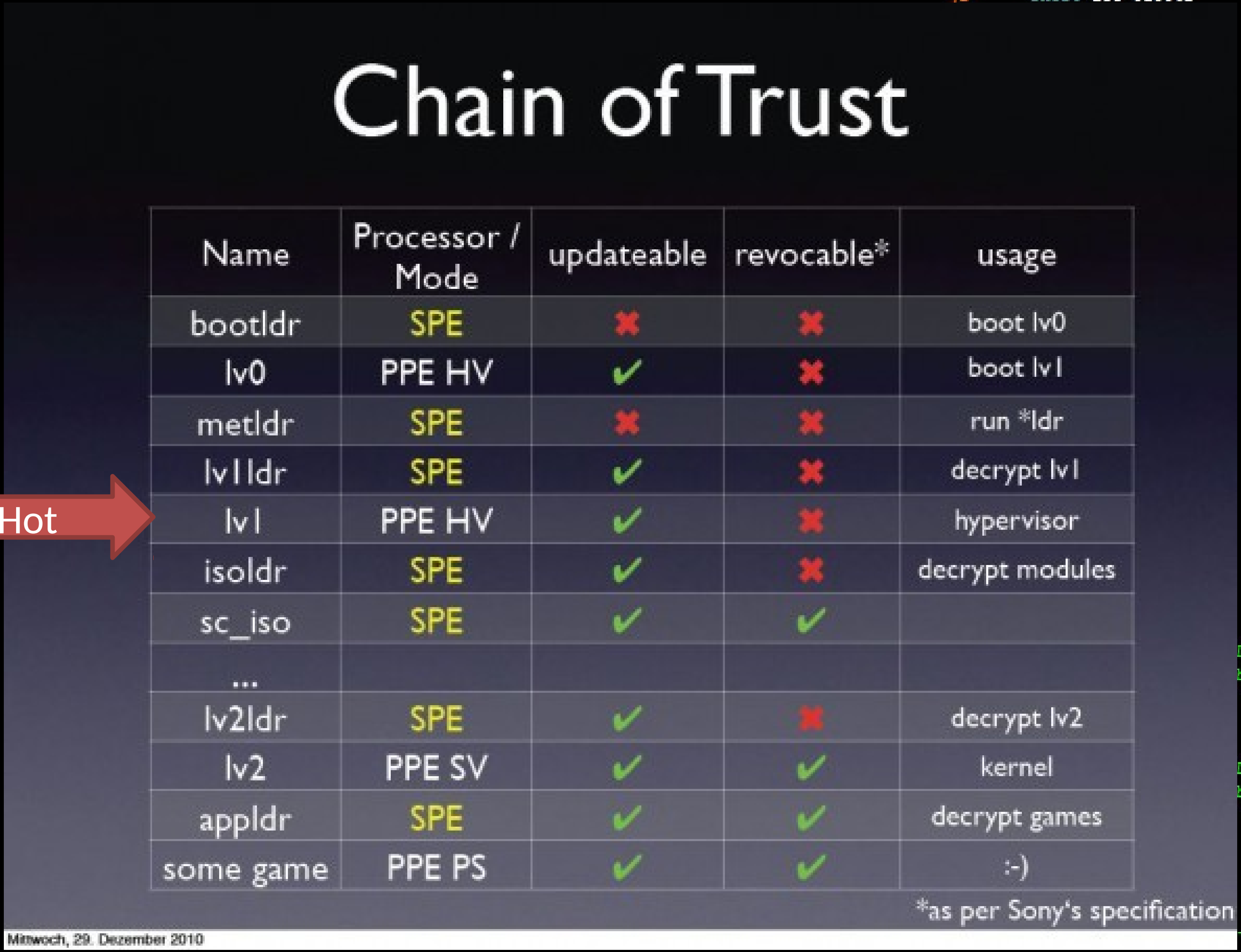
GeoHot Owns PS3 Hv – Jan. 2010

- Through OtherOS (Linux on PS3) and chip glitching, GeoHot owns the PS3 Hypervisor
- Glitching ‘creates’ a use after free scenario in the Hypervisor that is then exploited to get code exec
- Dumps of PS3 HV & kernel make their way public

```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_70]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
push    esi
```

```
call    sub_3140F3
and     eax, 0FFFFh
or      eax, 80070000h

loc_31308C:                     ; CODE XREF: sub_312FD8
mov     [ebp+var_4], eax
```

```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
```



Chain of Trust

Name	Processor / Mode	updateable	revocable*	usage
bootldr	SPE	✖	✖	boot lv0
lv0	PPE HV	✓	✖	boot lv1
metldr	SPE	✖	✖	run *ldr
lv1ldr	SPE	✓	✖	decrypt lv1
lv1	PPE HV	✓	✖	hypervisor
isoldr	SPE	✓	✖	decrypt modules
sc_iso	SPE	✓	✓	
...				
lv2ldr	SPE	✓	✖	decrypt lv2
lv2	PPE SV	✓	✓	kernel
appldr	SPE	✓	✓	decrypt games
some game	PPE PS	✓	✓	:-)

*as per Sony's specification

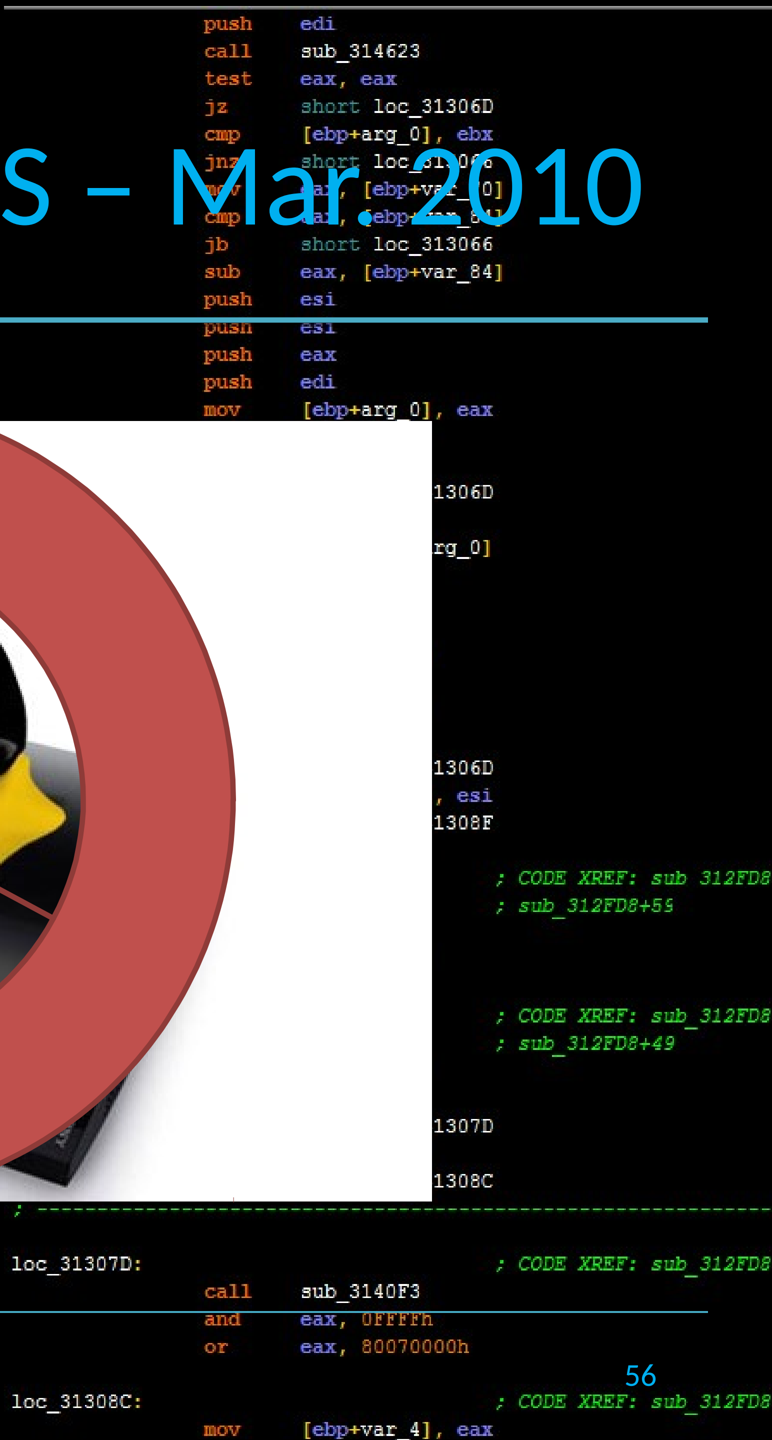
Mittwoch, 29. Dezember 2010

GeoHot

More Privileged

```
loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

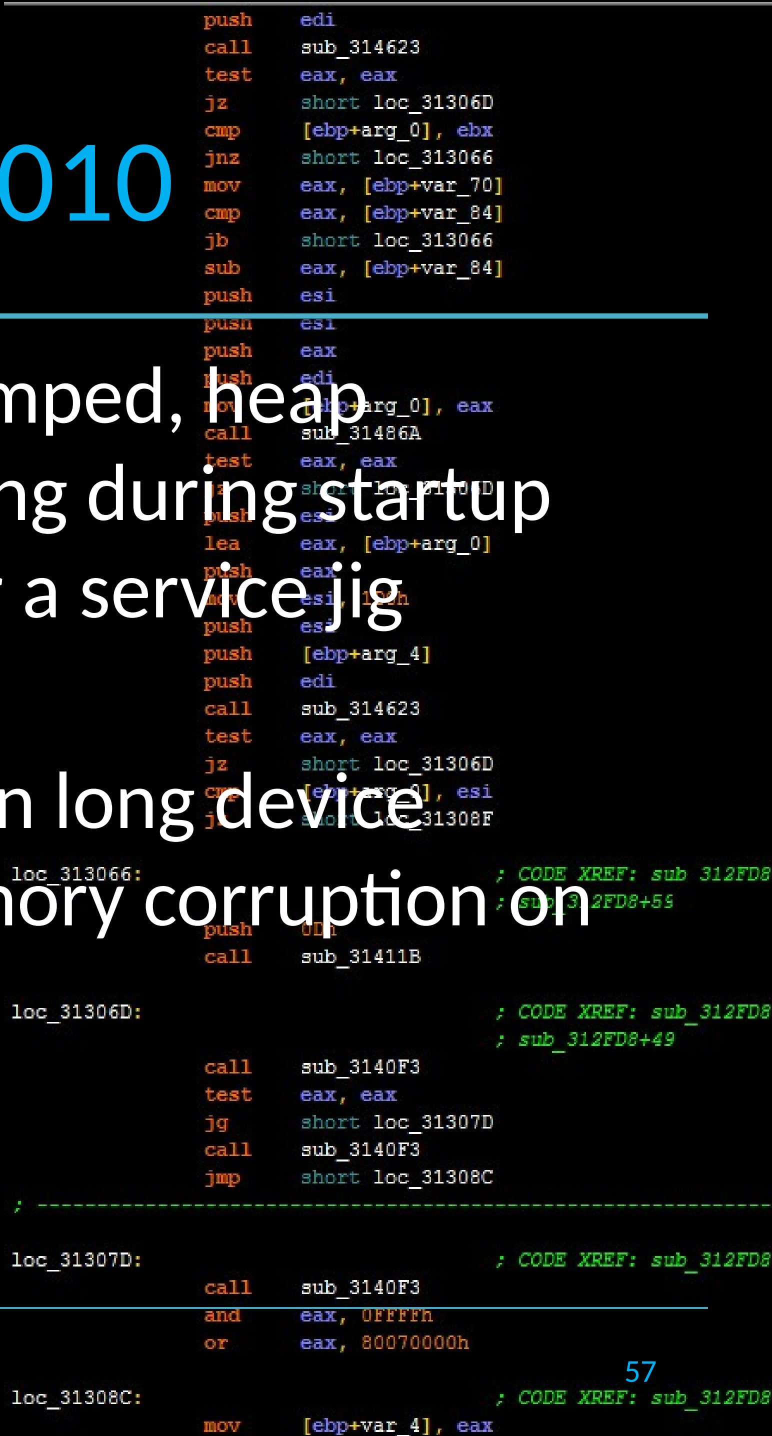
Sony Disables OtherOS – Mar.2010



```
        push    edi
        call    sub_314623
        test    eax, eax
        jz      short loc_31306D
        cmp     [ebp+arg_0], ebx
        jnz     short loc_31306[illegible]
        mov     eax, [ebp+var_[illegible]0]
        cmp     eax, [ebp+var_8[illegible]]
        jb      short loc_313066
        sub     eax, [ebp+var_84]
        push    esi
        push    esi
        push    eax
        push    edi
        mov     [ebp+arg_0], eax

                1306D

                rg_0]

                1306D
                , esi
                1308F
                                ; CODE XREF: sub_312FD8
                                ; sub_312FD8+55

                                ; CODE XREF: sub_312FD8
                                ; sub_312FD8+49

                1307D

                1308C
; ---------------------------------------------------------------

loc_31307D:                     ; CODE XREF: sub_312FD8
        call    sub_3140F3
        and     eax, 0FFFFh
        or      eax, 80070000h

loc_31308C:                     ; CODE XREF: sub_312FD8
        mov     [ebp+var_4], eax
```

PS3 Jailbreak – Aug. 2010

- With the PS3 Kernel (LV2) dumped, heap overflow found in USB handling during startup while the system searches for a service jig
- The main bug is an overflow in long device descriptors that leads to memory corruption on the heap
- Results in control of the LV2



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, [illegible]
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jnz     short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+59
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

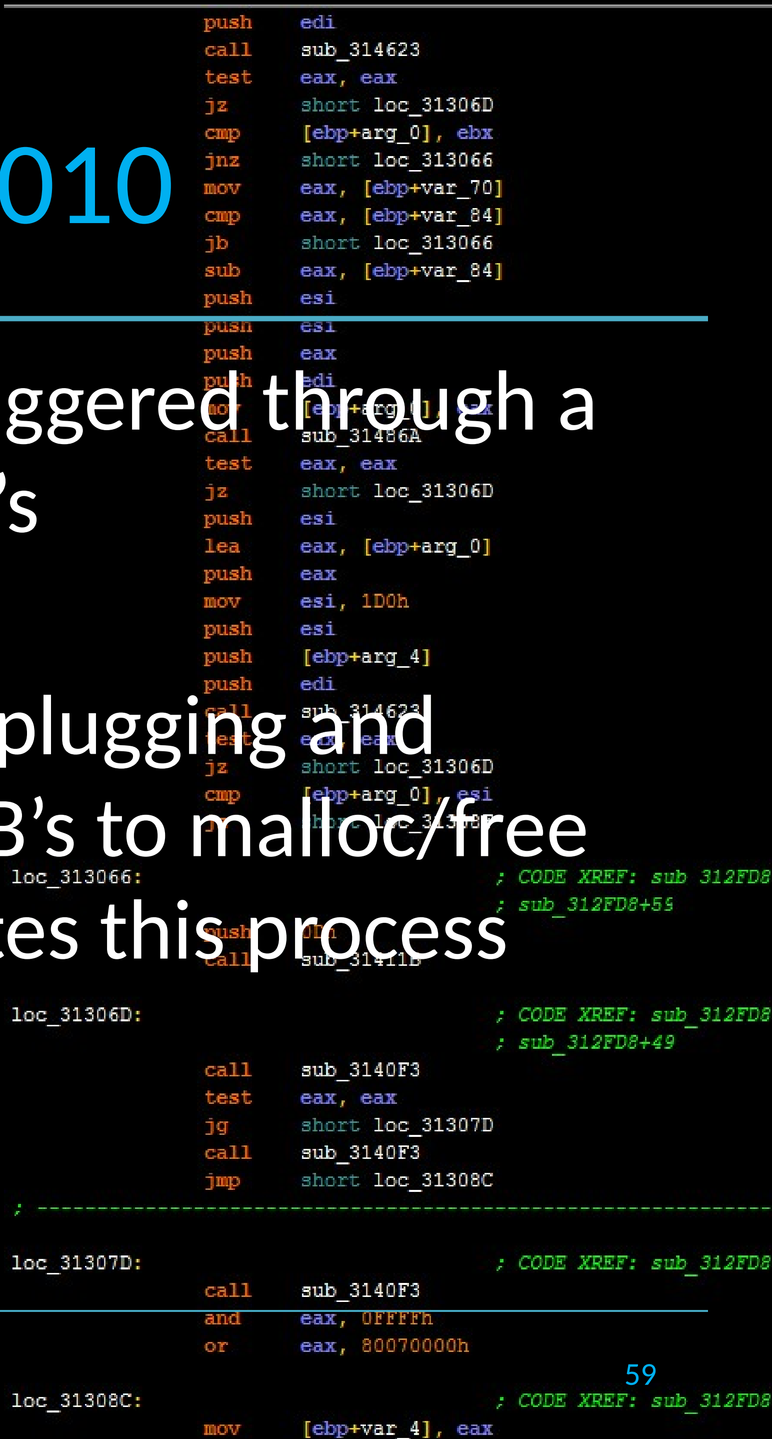
```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_70]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
push    esi
```

PS3 Jailbreak – Aug. 2010

```
 eax
306D
g_0]
306D
 esi
308F
 ; CODE XREF: sub_312FD8
 ; sub_312FD8+55
 ; CODE XREF: sub_312FD8
 ; sub_312FD8+49
307D
308C
---------------------------
 ; CODE XREF: sub_312FD8
call    sub_3140F3
and     eax, 0FFFFh
or      eax, 80070000h

loc_31308C:                              ; CODE XREF: sub_312FD8
mov     [ebp+var_4], eax
```

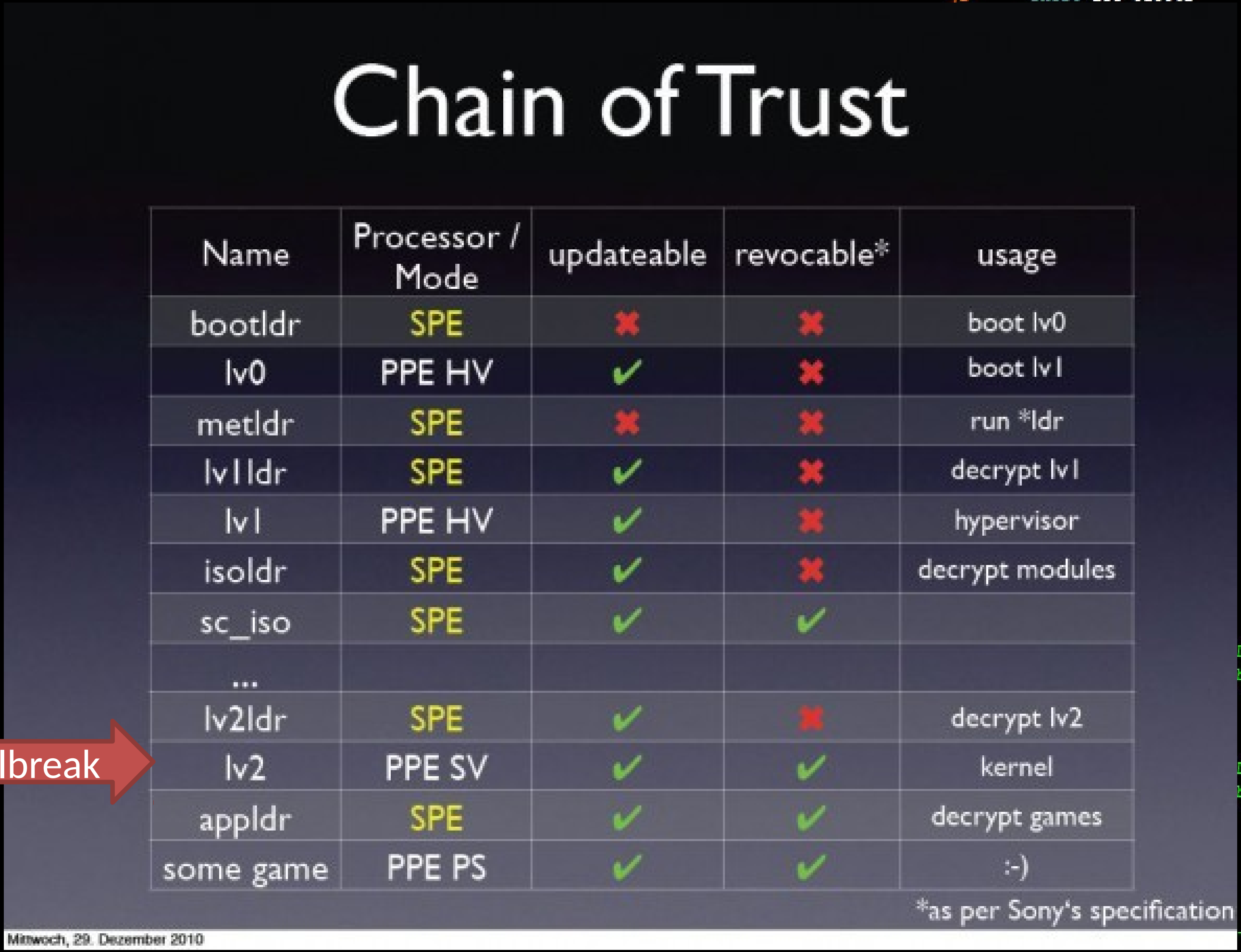
PS3 Jailbreak – Aug. 2010

- Heap overflow setup and triggered through a <u>USB hub</u> (oops) and six USB’s
- It’s a bit like musical chairs, plugging and unplugging a number of USB’s to malloc/free stuff – everyone just emulates this process with a single USB



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], ebx
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                [illegible] short loc_3130[illegible]

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+59
                push    edi
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

```
        push    edi
        call    sub_314623
        test    eax, eax
        jz      short loc_31306D
```



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lv1	PPE HV	✓	✗	hypervisor
isoldr	SPE	✓	✗	decrypt modules
sc_iso	SPE	✓	✓	
...				
lv2ldr	SPE	✓	✗	decrypt lv2
lv2	PPE SV	✓	✓	kernel
appldr	SPE	✓	✓	decrypt games
some game	PPE PS	✓	✓	:-)

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Mittwoch, 29. Dezember 2010

PS3 Jailbreak

More Privileged

```
loc_31307D:                              ; CODE XREF: sub_312FD8
        call    sub_3140F3
        and     eax, 0FFFFh
        or      eax, 80070000h

loc_31308C:                              ; CODE XREF: sub_312FD8
        mov     [ebp+var_4], eax
```

PS3 ECDSA KEY EXTRACTION

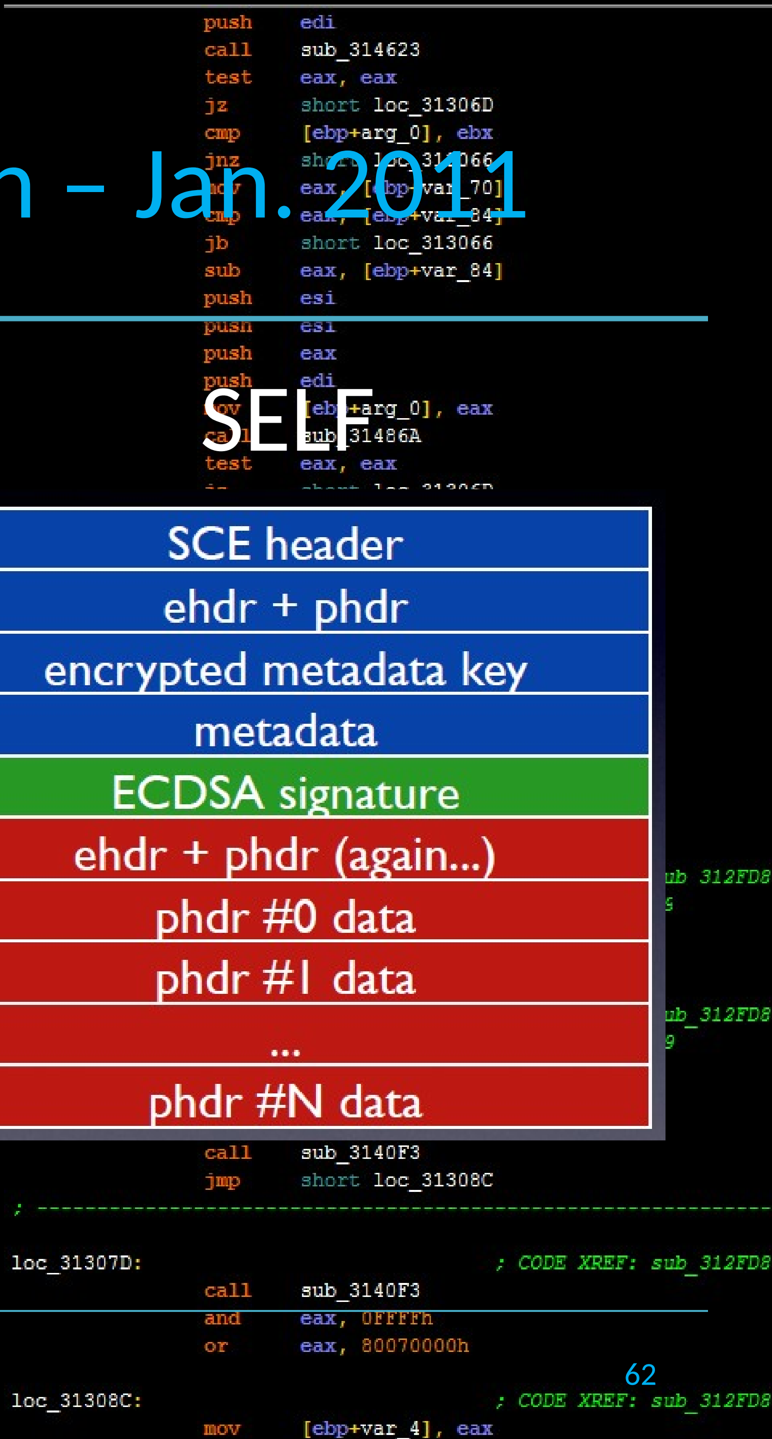
Largest console break of this generation stems from crypto flaw

```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+59
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

PS3 ECDSA Key Extraction – Jan. 2011

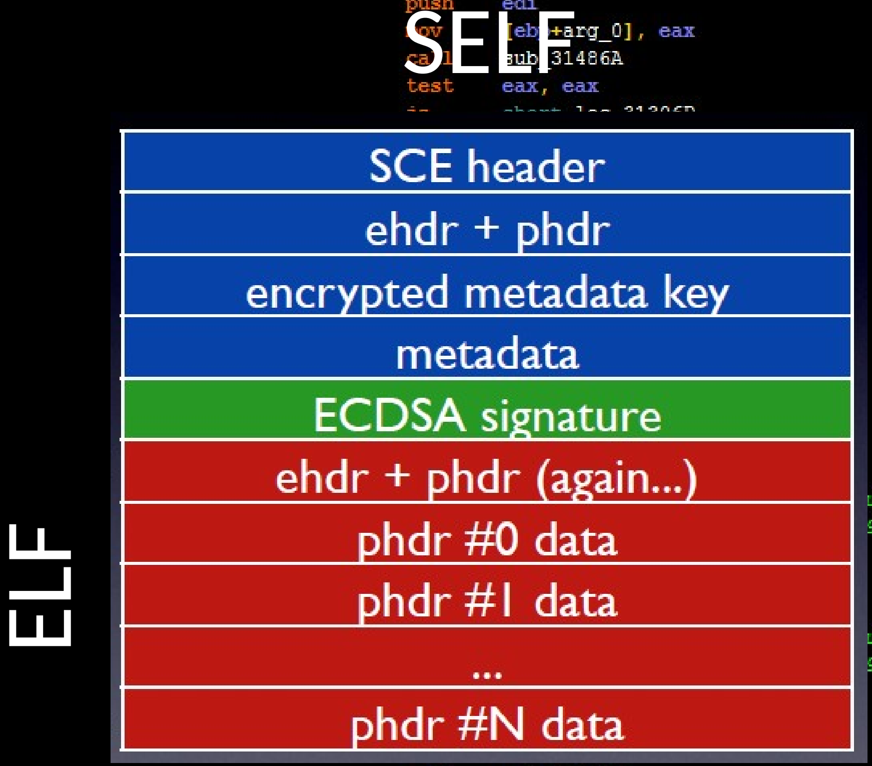
- Executables running on the PS3 are modified ELF's known as SELF's

- Signed by Sony's ECDSA Key, encrypted by the associated Lv(0,1,2) keys
  - Elliptic Curve Digital Signature Algorithm



```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_70]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
push    esi
push    eax
push    edi
mov     [ebp+arg_0], eax
call    sub_31486A
test    eax, eax
```

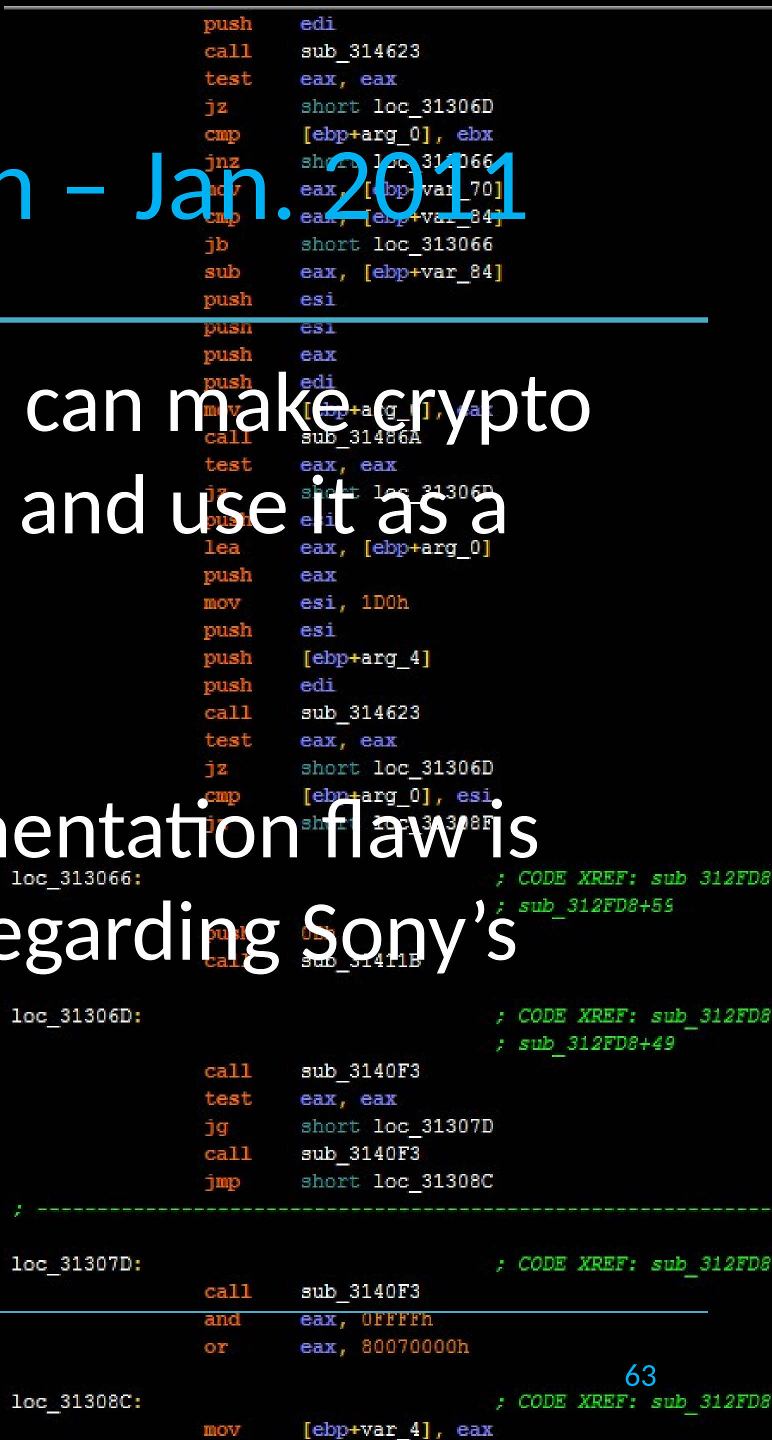
```
call    sub_3140F3
jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
call    sub_3140F3
and     eax, 0FFFFh
or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
mov     [ebp+var_4], eax
```



PS3 ECDSA Key Extraction – Jan. 2011

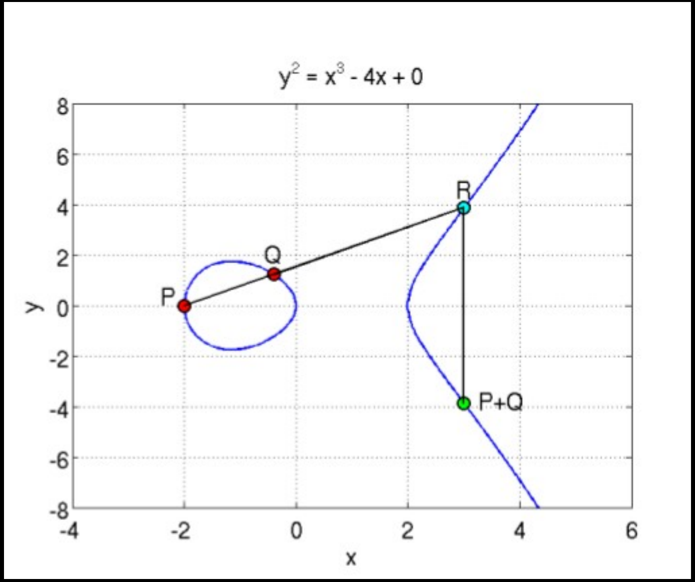
- With control of the LV2, you can make crypto requests to the security SPE and use it as a black box

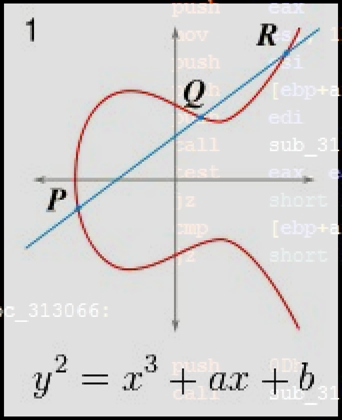
- An egregious crypto implementation flaw is uncovered by fail0verflow regarding Sony's ECDSA signatures



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    [illegible]
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

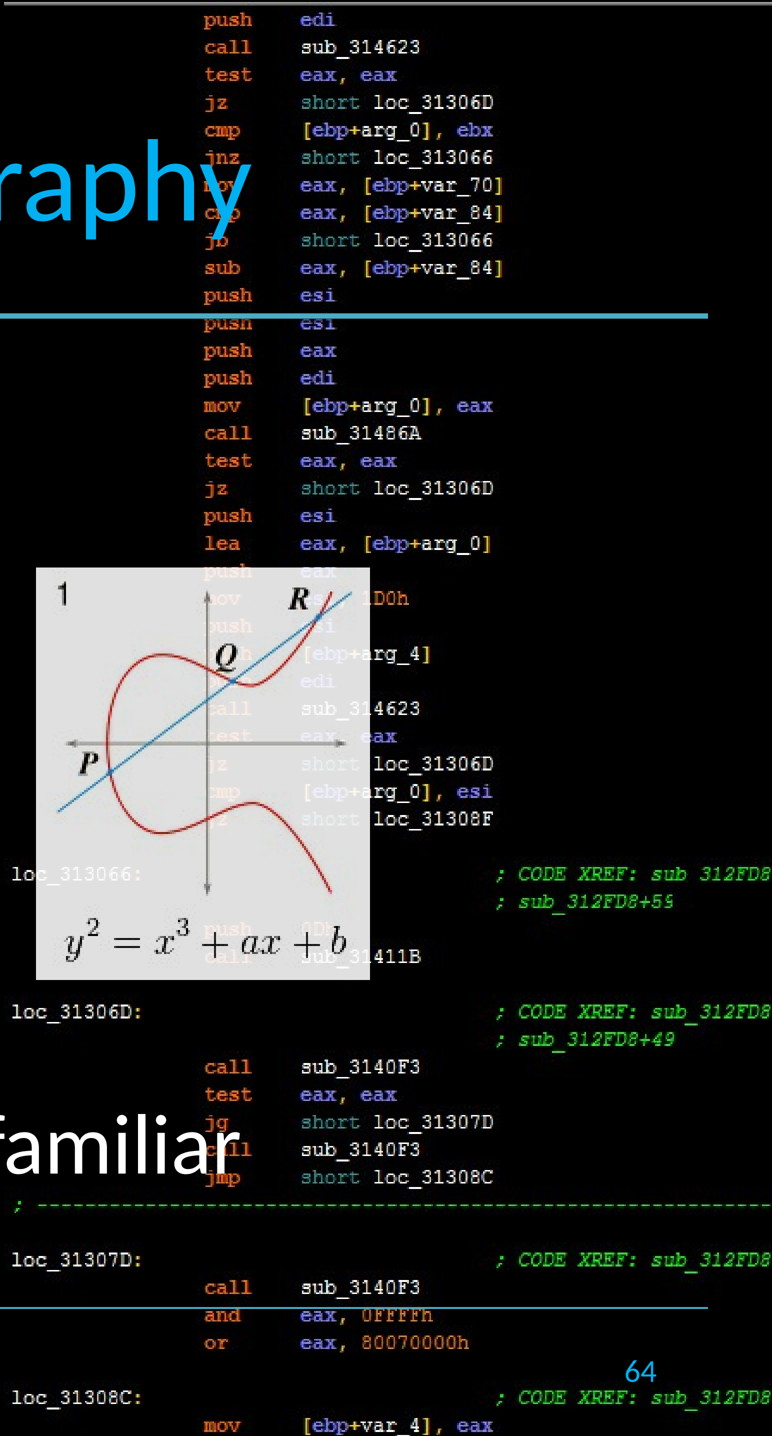
Elliptic Curve Cryptography





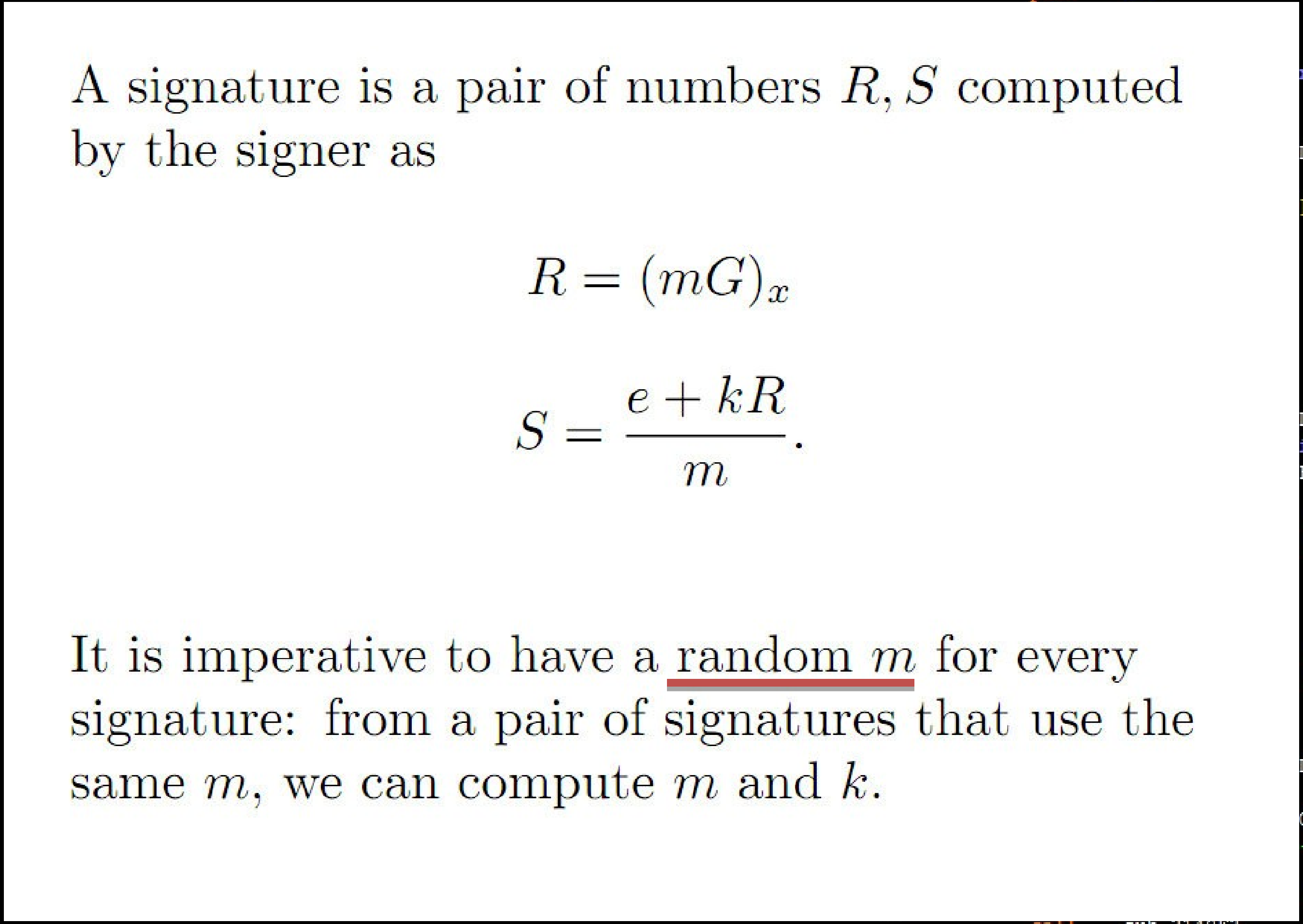
$$y^2 = x^3 + ax + b$$

these might look familiar



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; -------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

Const Instead of Nonce



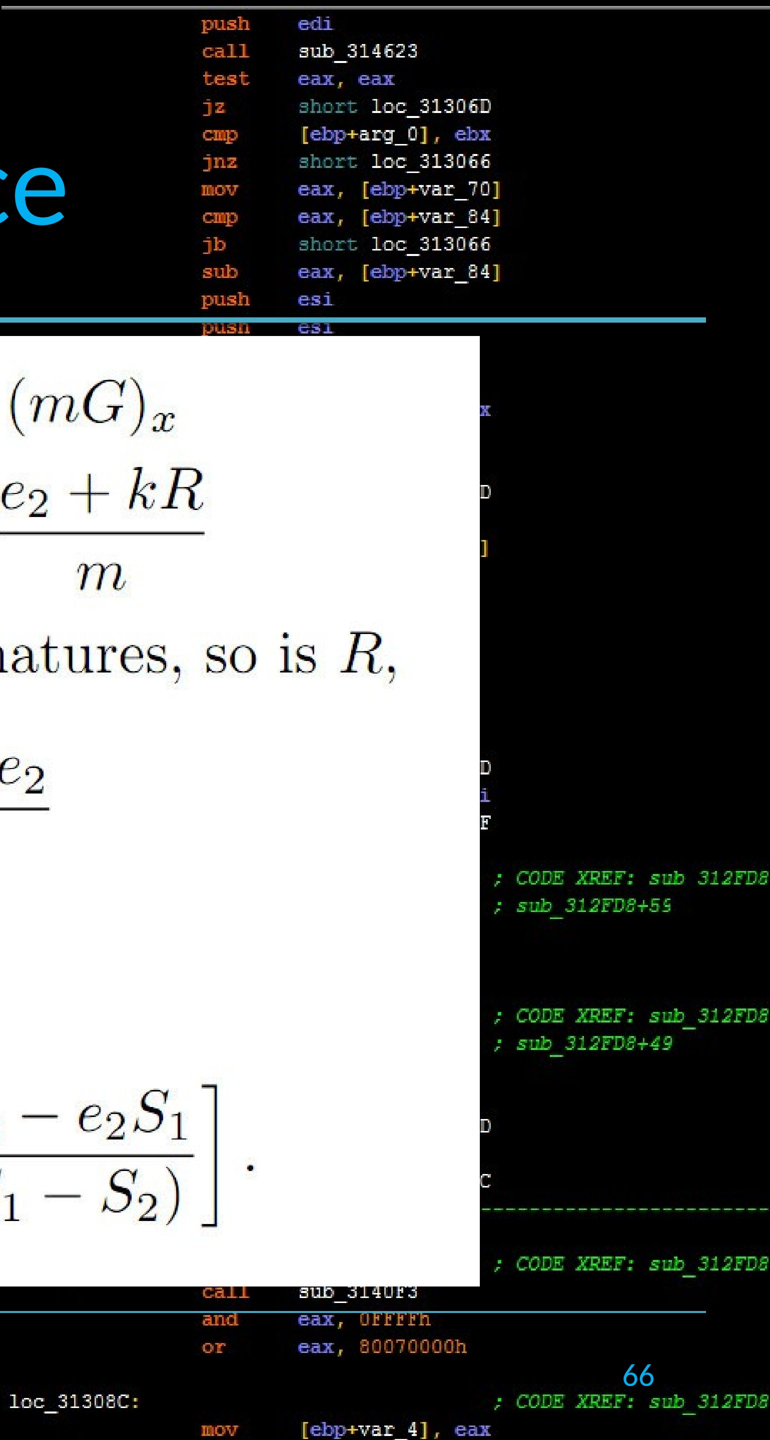
A signature is a pair of numbers R, S computed by the signer as

$$R = (mG)_x$$

$$S = \frac{e + kR}{m}.$$

It is imperative to have a $\underline{\text{random } m}$ for every signature: from a pair of signatures that use the same m, we can compute m and k.

Const Instead of Nonce



```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_70]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
push    esi
```

```
; CODE XREF: sub_312FD8
; sub_312FD8+55
; CODE XREF: sub_312FD8
; sub_312FD8+49
; CODE XREF: sub_312FD8
call    sub_3140F3
and     eax, 0FFFFh
or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
mov     [ebp+var_4], eax
```

$$R = (mG)_x \qquad R = (mG)_x$$

$$S_1 = \frac{e_1 + kR}{m} \qquad S_2 = \frac{e_2 + kR}{m}$$

When m is identical for two signatures, so is R, and

$$S_1 - S_2 = \frac{e_1 - e_2}{m}$$

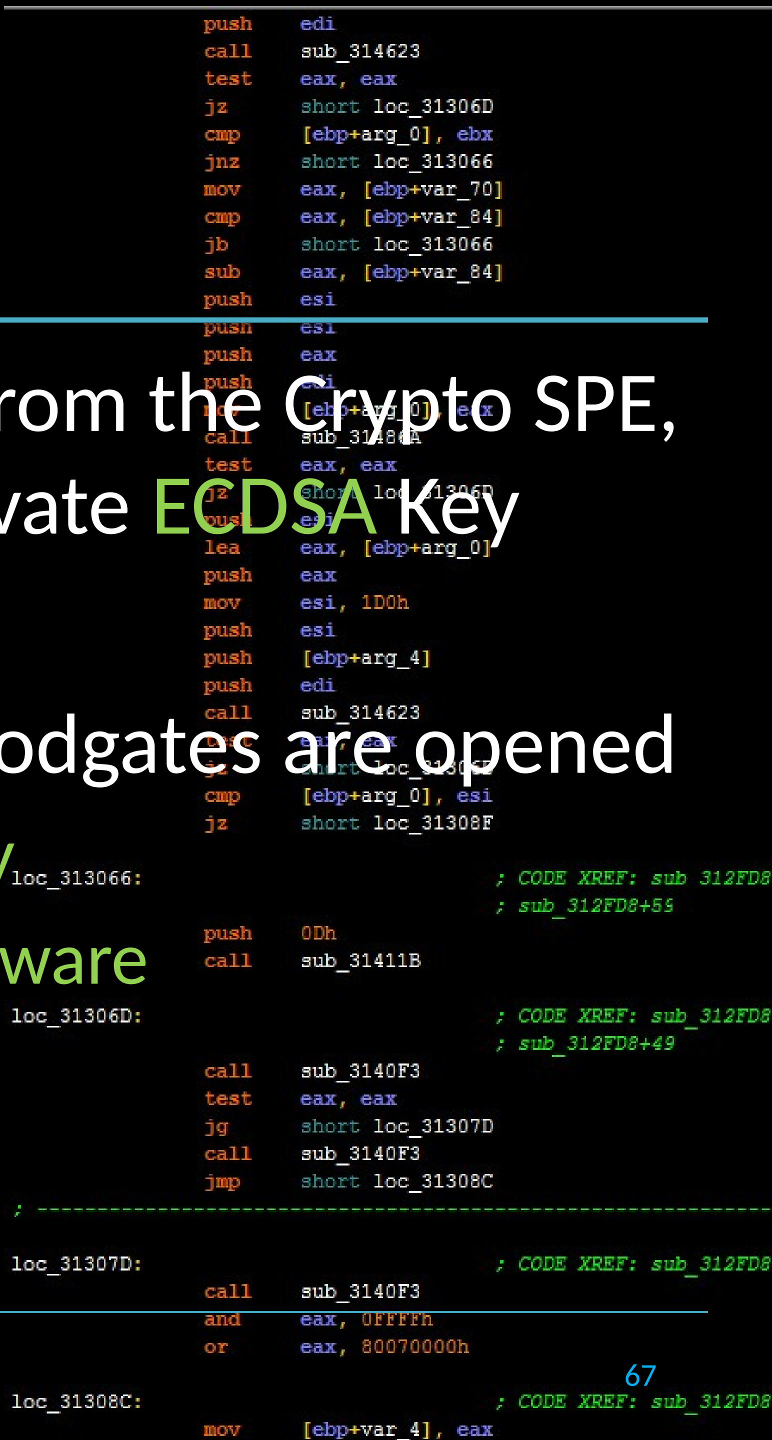
$$m = \frac{e_1 - e_2}{S_1 - S_2}$$

$$k = \frac{mS_i - e_i}{R} \quad \left[= \frac{e_1 S_2 - e_2 S_1}{R(S_1 - S_2)} \right].$$

Effects of Missteps

- With only TWO signatures from the Crypto SPE, you can compute Sony’s Private ECDSA Key

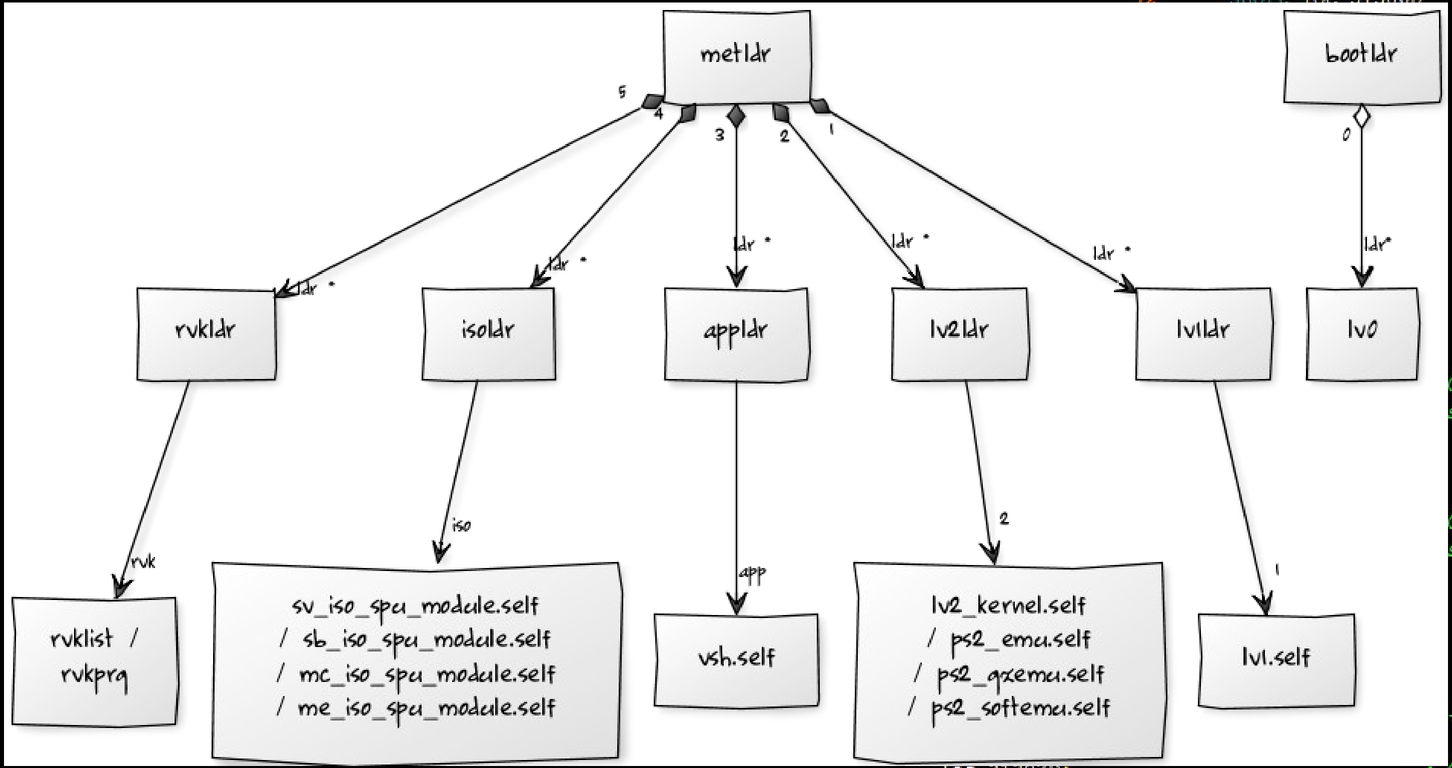
- With the ECDSA Key, the floodgates are opened
  - You can sign anything as Sony
  - This key is embedded in hardware



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                [illegible] [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31308F
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

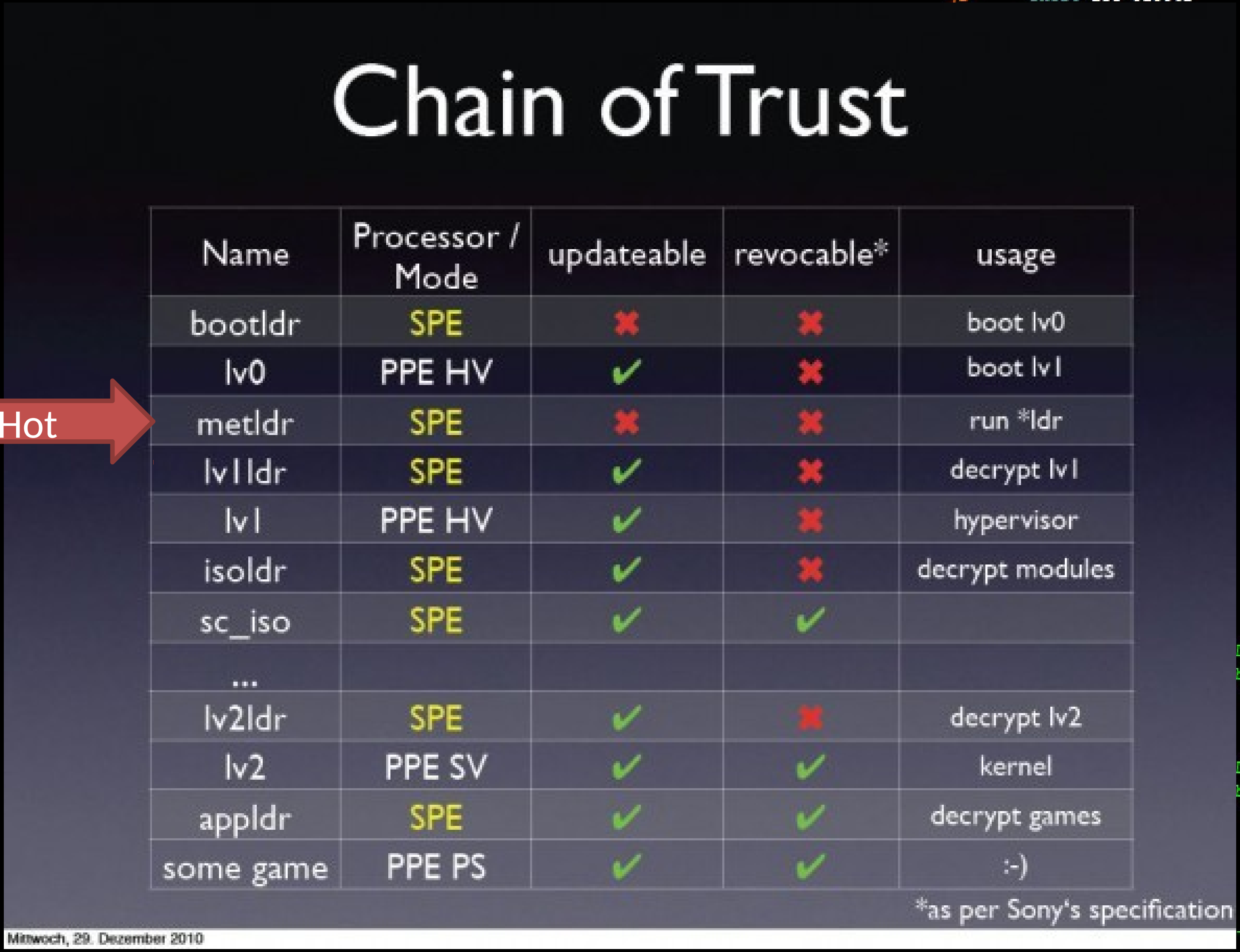
metldr Owned

- Geohot releases metldr decryption keys



metldr
bootldr
5
4
3
2
1
0
ldr *
ldr*
rvkldr
isoldr
appldr
lv2ldr
lv1ldr
lv0
rvk
iso
app
2
1
rvklist / rvkprg
sv_iso_spu_module.self / sb_iso_spu_module.self / mc_iso_spu_module.self / me_iso_spu_module.self
vsh.self
lv2_kernel.self / ps2_emu.self / ps2_gxemu.self / ps2_softemu.self
lv1.self

```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
```



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lv1ldr	SPE	✓	✗	decrypt lv1
lv1	PPE HV	✓	✗	hypervisor
isoldr	SPE	✓	✗	decrypt modules
sc_iso	SPE	✓	✓	
...				
lv2ldr	SPE	✓	✗	decrypt lv2
lv2	PPE SV	✓	✓	kernel
appldr	SPE	✓	✓	decrypt games
some game	PPE PS	✓	✓	:-)

*as per Sony's specification

Mittwoch, 29. Dezember 2010

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```
loc_31307D:                             ; CODE XREF: sub_312FD8
        call    sub_3140F3
        and     eax, 0FFFFh
        or      eax, 80070000h

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        mov     [ebp+var_4], eax
```
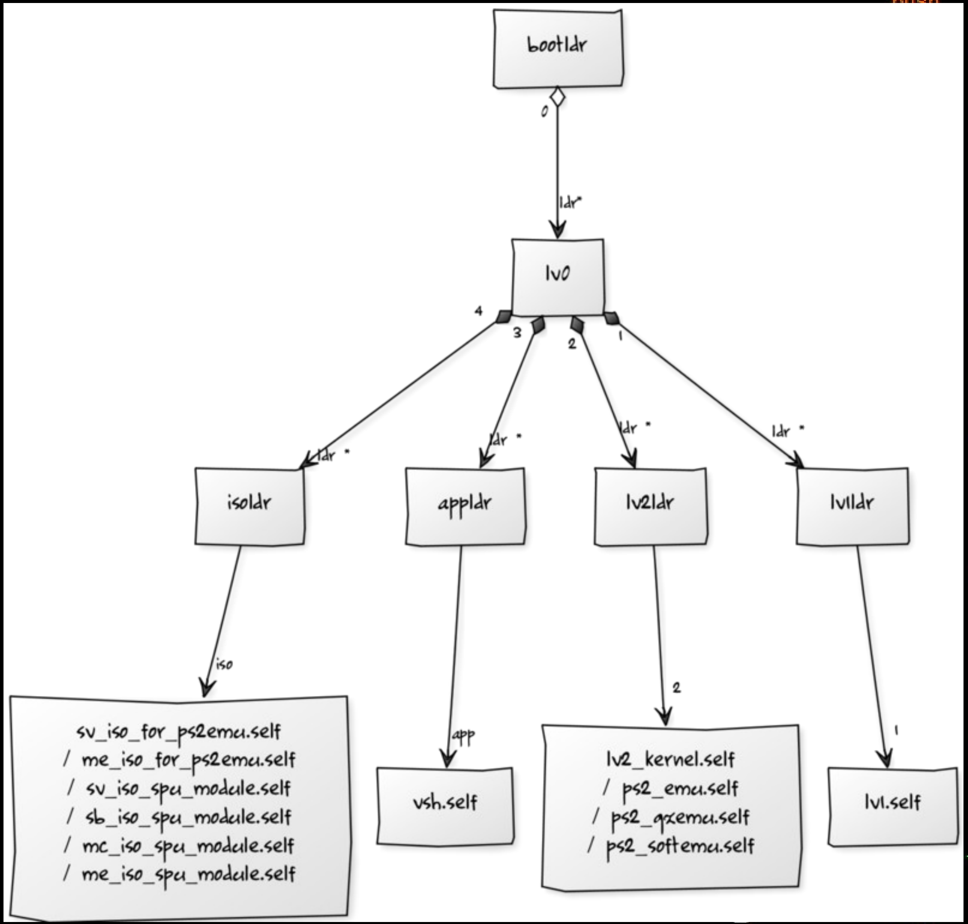

Sony Nukes metldr

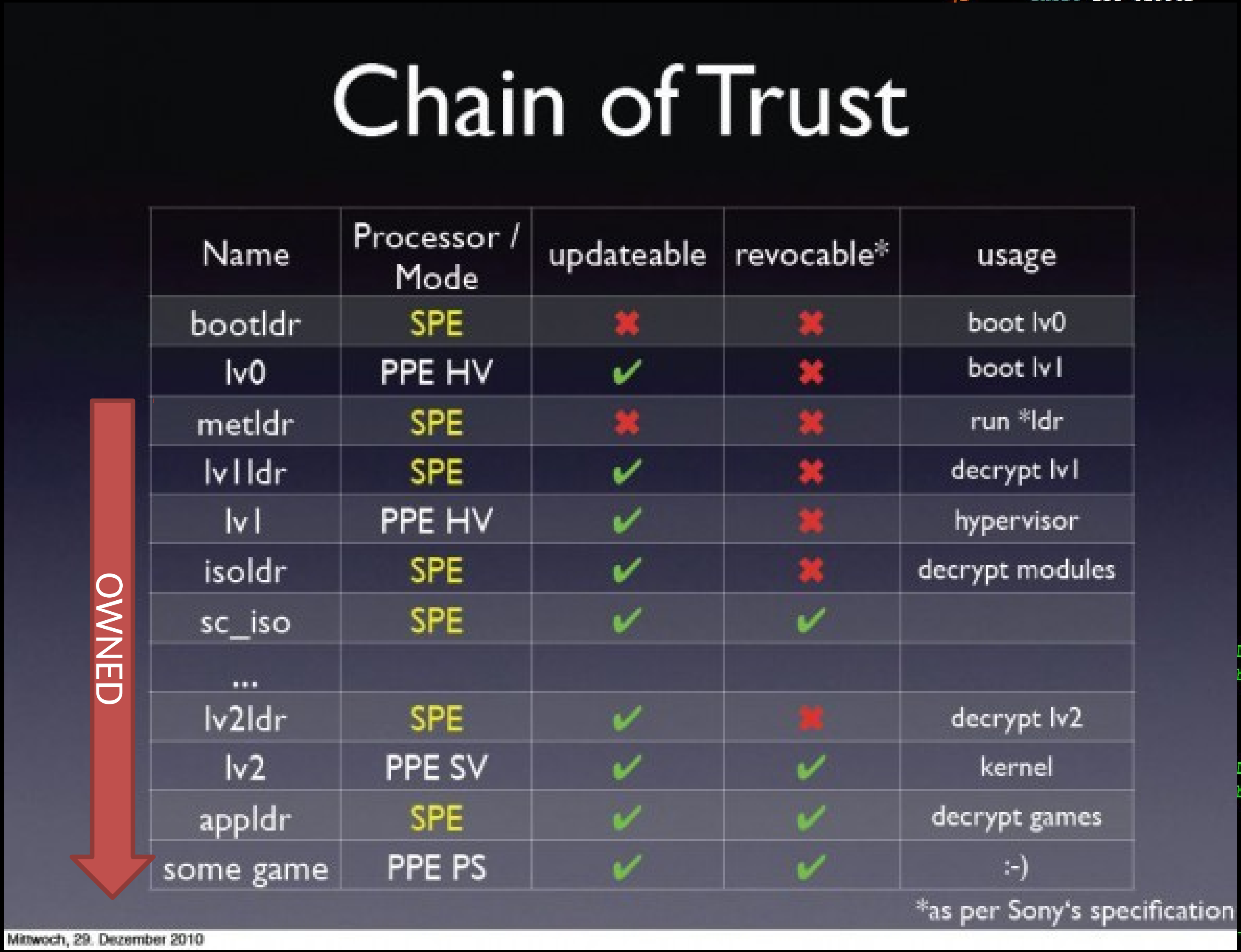
```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
cmp     [ebp+arg_0], ebx
jnz     short loc_313066
mov     eax, [ebp+var_70]
cmp     eax, [ebp+var_84]
jb      short loc_313066
sub     eax, [ebp+var_84]
push    esi
push    esi
push    eax
        edi
        [ebp+arg_0], eax
        sub_31486A
        eax, eax
        short loc_31306D
        esi
        eax, [ebp+arg_0]
        eax
        esi, 1D0h
        esi
        [ebp+arg_4]
        edi
        sub_314623
        eax, eax
        short loc_31306D
        [ebp+arg_0], esi
        short loc_31308F

                        ; CODE XREF: sub_312FD8
                        ; sub_312FD8+55
        0Dh
        sub_31411B

                        ; CODE XREF: sub_312FD8
                        ; sub_312FD8+49
        sub_3140F3
        eax, eax
        short loc_31307D
        sub_3140F3
        short loc_31308C
----------------------------------------------

                        ; CODE XREF: sub_312FD8
call    sub_3140F3
and     eax, 0FFFFh
or      eax, 80070000h

loc_31308C:             ; CODE XREF: sub_312FD8
mov     [ebp+var_4], eax
```



bootldr
0
ldr*
lv0
4
3
2
1
ldr *
ldr *
ldr *
ldr *
isoldr
appldr
lv2ldr
lv1ldr
iso
app
2
1
sv_iso_for_ps2emu.self / me_iso_for_ps2emu.self / sv_iso_spu_module.self / sb_iso_spu_module.self / mc_iso_spu_module.self / me_iso_spu_module.self
vsh.self
lv2_kernel.self / ps2_emu.self / ps2_gxemu.self / ps2_softemu.self
lv1.self

Sony Sues Geohot – Jan. 2011

```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
```



Chain of Trust

Name	Processor / Mode	updateable	revocable*	usage
bootldr	SPE	✗	✗	boot lv0
lv0	PPE HV	✓	✗	boot lv1
metldr	SPE	✗	✗	run *ldr
lv1ldr	SPE	✓	✗	decrypt lv1
lv1	PPE HV	✓	✗	hypervisor
isoldr	SPE	✓	✗	decrypt modules
sc_iso	SPE	✓	✓	
...				
lv2ldr	SPE	✓	✗	decrypt lv2
lv2	PPE SV	✓	✓	kernel
appldr	SPE	✓	✓	decrypt games
some game	PPE PS	✓	✓	:-)

*as per Sony's specification

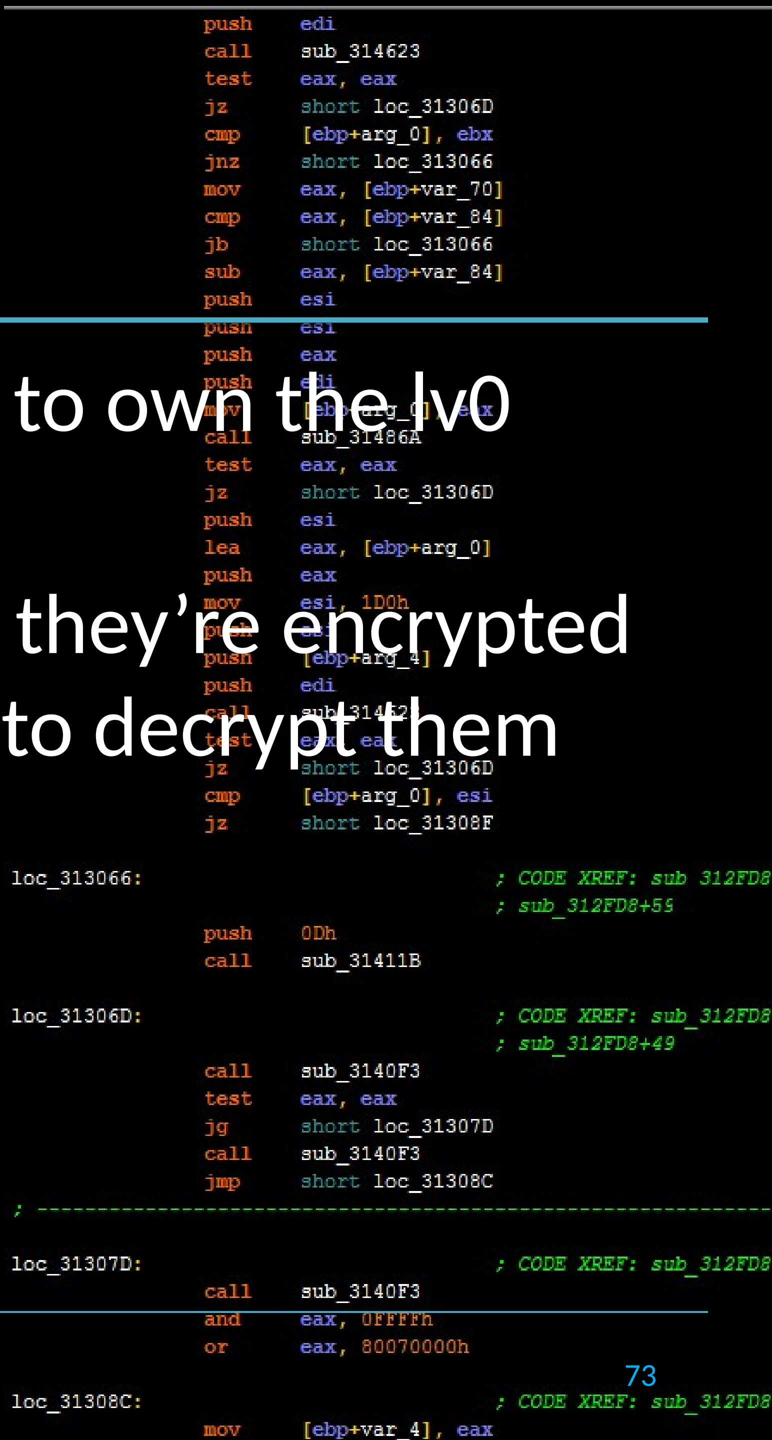
Mittwoch, 29. Dezember 2010

OWNED
More Privileged

```
loc_31307D:                             ; CODE XREF: sub_312FD8
        call    sub_3140F3
        and     eax, 0FFFFh
        or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
        mov     [ebp+var_4], eax
```

Owning the lv0

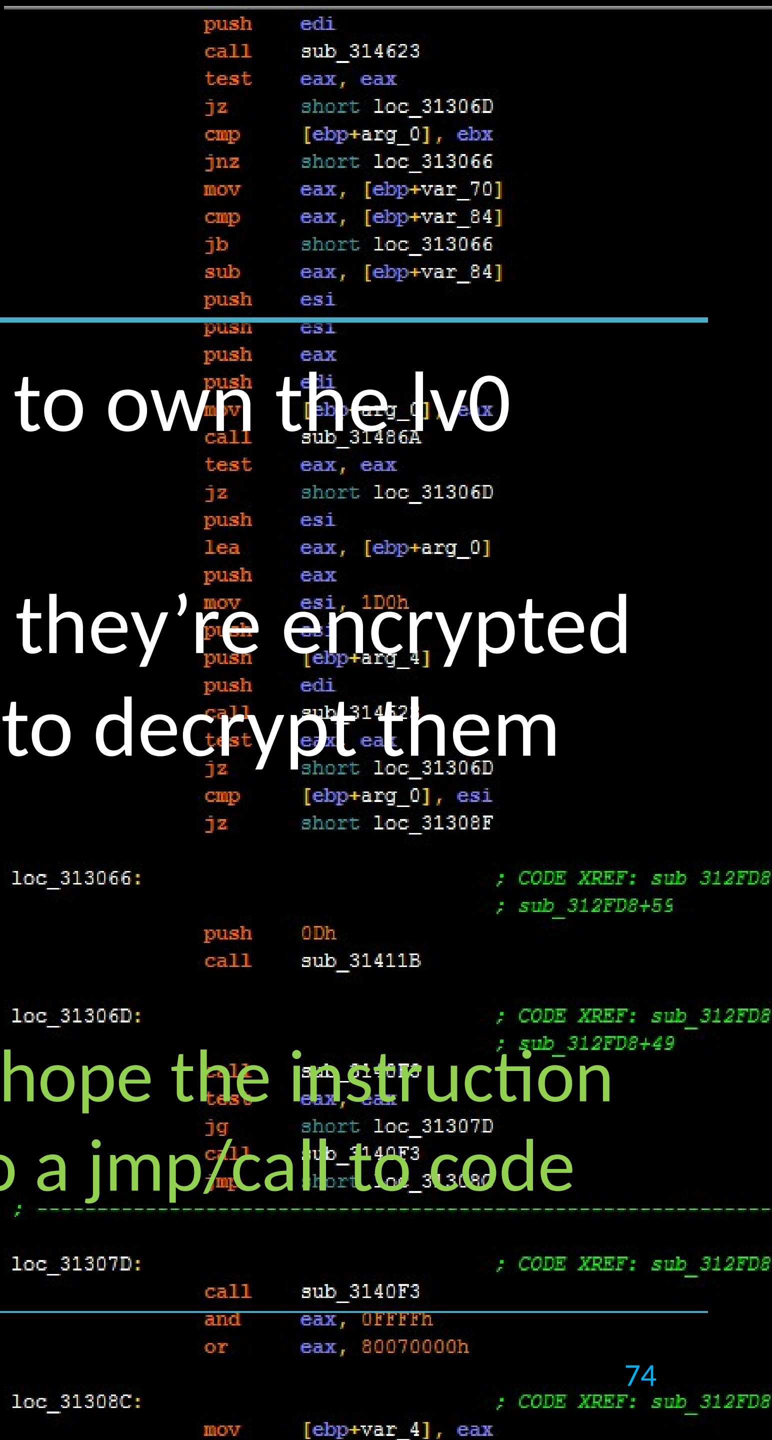
- metldr is gone, so you need to own the lv0
- lv0 blobs can be signed, but they’re encrypted and we don’t have the keys to decrypt them
- What do you do?????



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

Owning the lv0

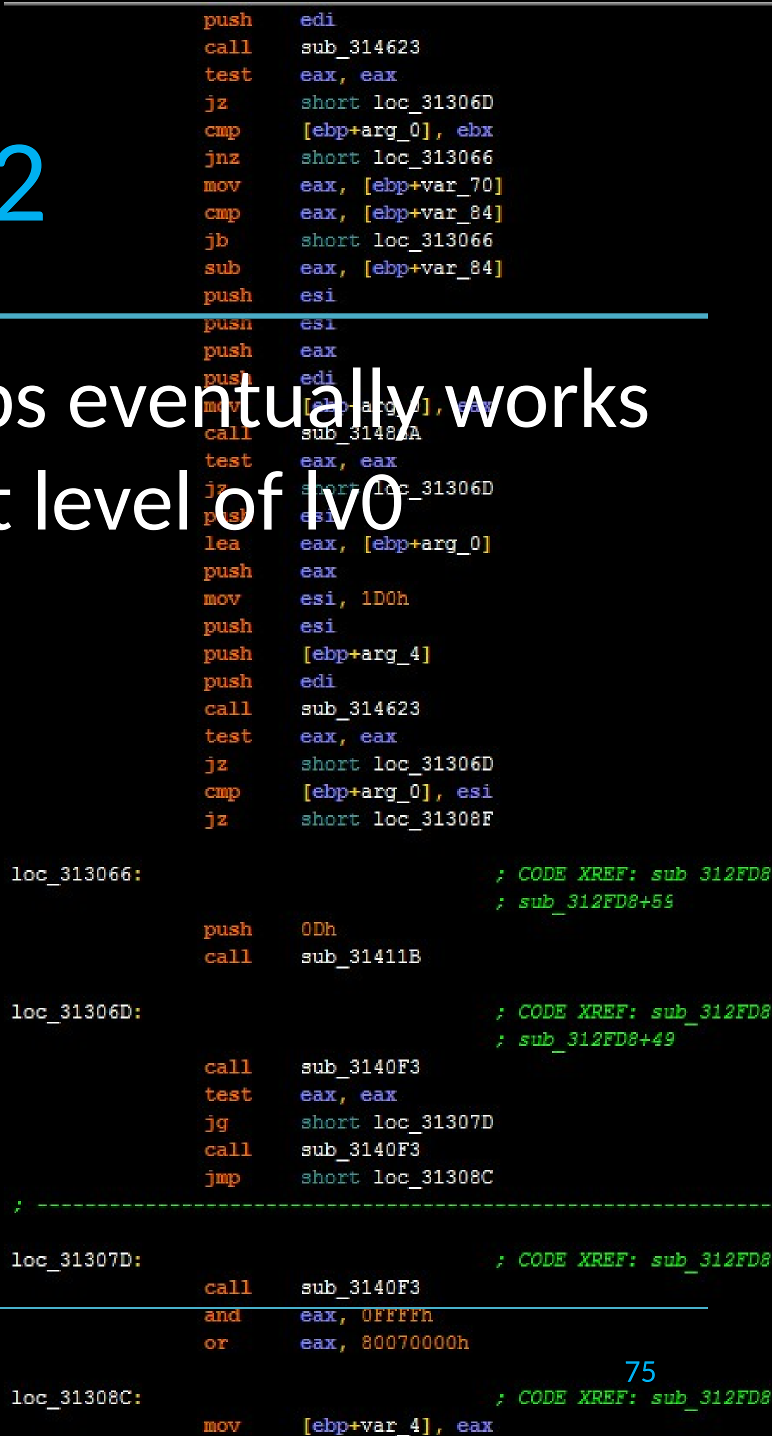
- metldr is gone, so you need to own the lv0
- lv0 blobs can be signed, but they're encrypted and we don't have the keys to decrypt them
- What do you do?????
  - Sign random data blobs, and hope the instruction at the entry point 'decrypt' to a jmp/call to code that you control



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

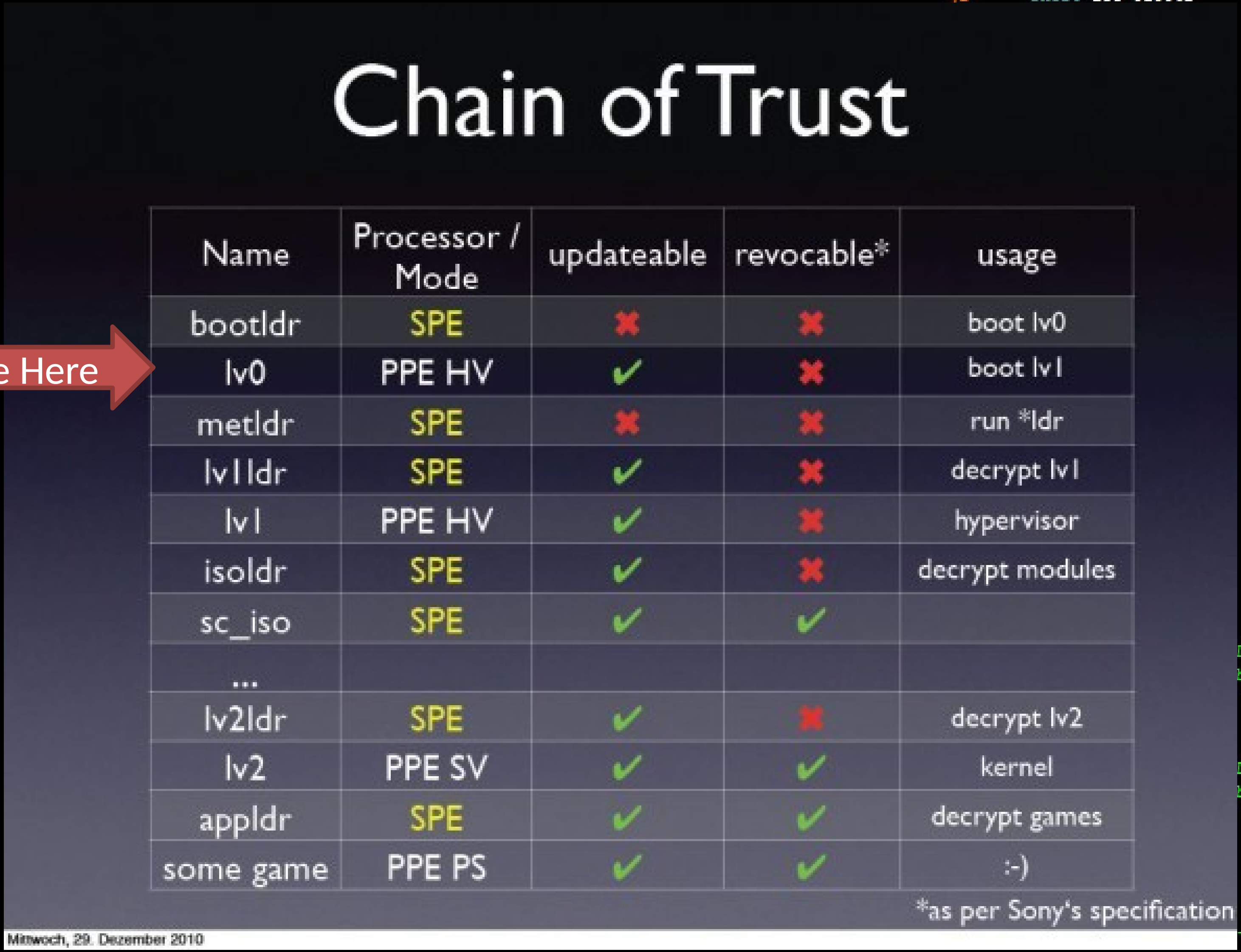
lv0 Owned – Oct. 2012

- Trying randomly signed blobs eventually works and execution is achieved at level of lv0



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_3148[illegible]A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+59
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

```
push    edi
call    sub_314623
test    eax, eax
jz      short loc_31306D
```



Chain of Trust

Name	Processor / Mode	updateable	revocable*	usage
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metldr	SPE	✗	✗	run *ldr
lv1ldr	SPE	✓	✗	decrypt lv1
lv1	PPE HV	✓	✗	hypervisor
isoldr	SPE	✓	✗	decrypt modules
sc_iso	SPE	✓	✓	
...				
lv2ldr	SPE	✓	✗	decrypt lv2
lv2	PPE SV	✓	✓	kernel
appldr	SPE	✓	✓	decrypt games
some game	PPE PS	✓	✓	:-)

*as per Sony's specification

Mittwoch, 29. Dezember 2010

You are Here

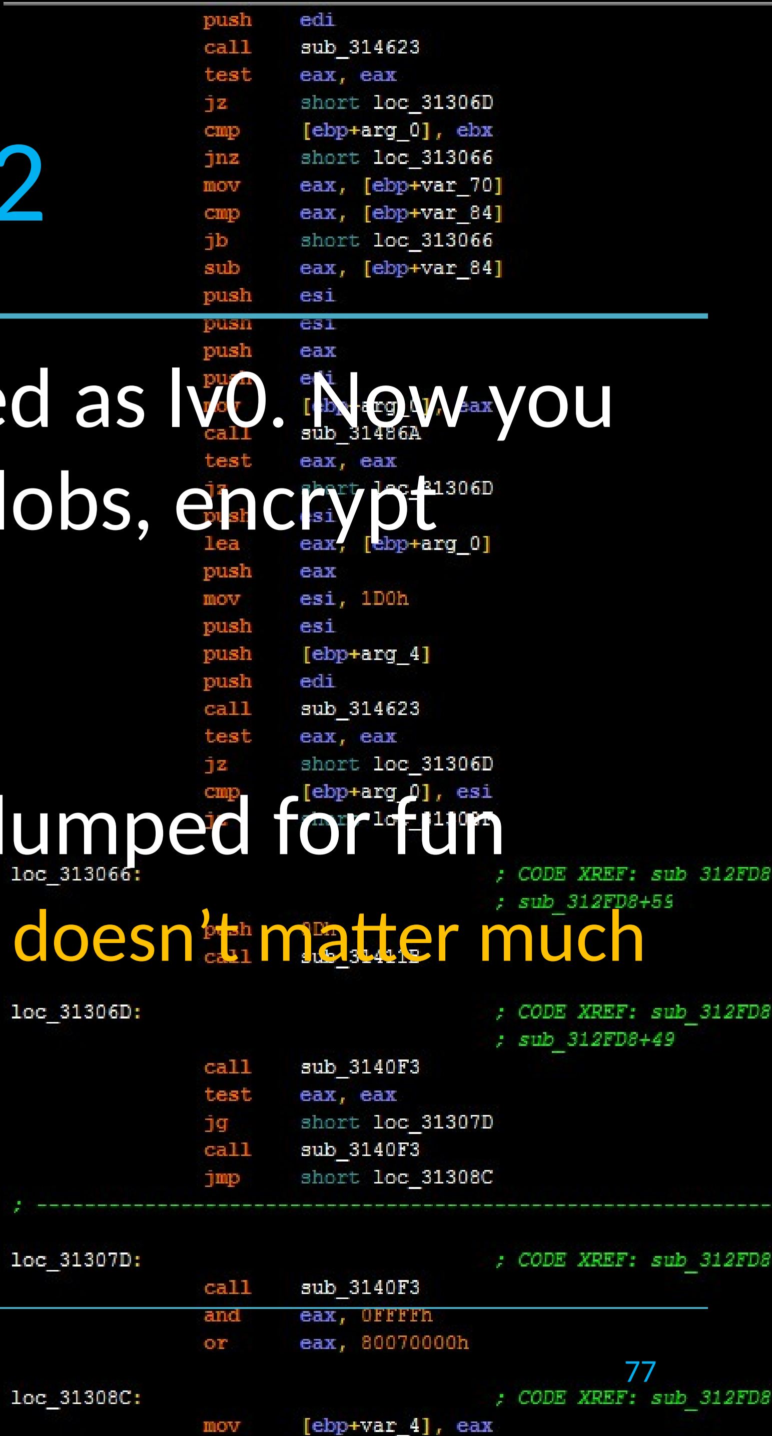
More Privileged

```
loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

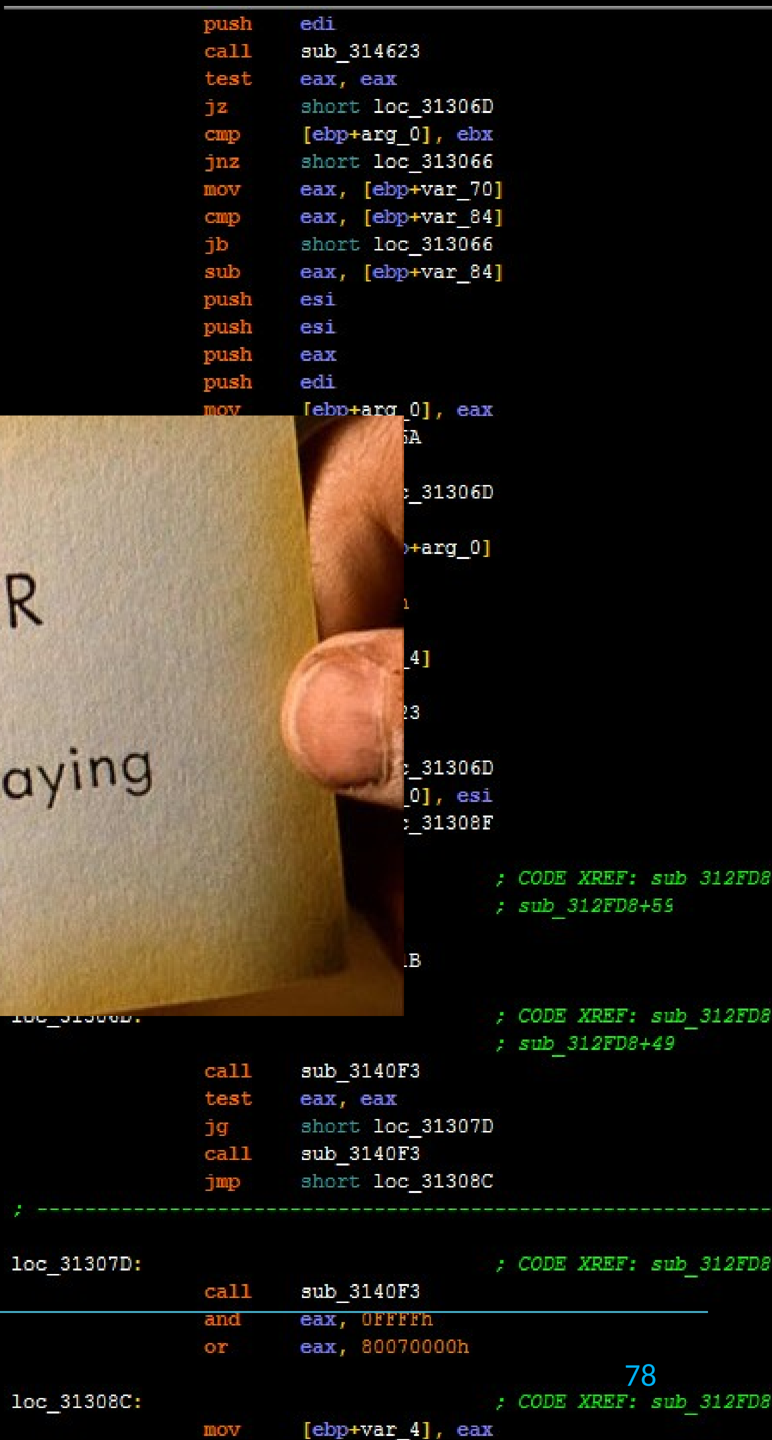
lv0 Owned – Oct. 2012

- Decryption keys are retrieved as lv0. Now you can create meaningful lv0 blobs, encrypt them, and sign them

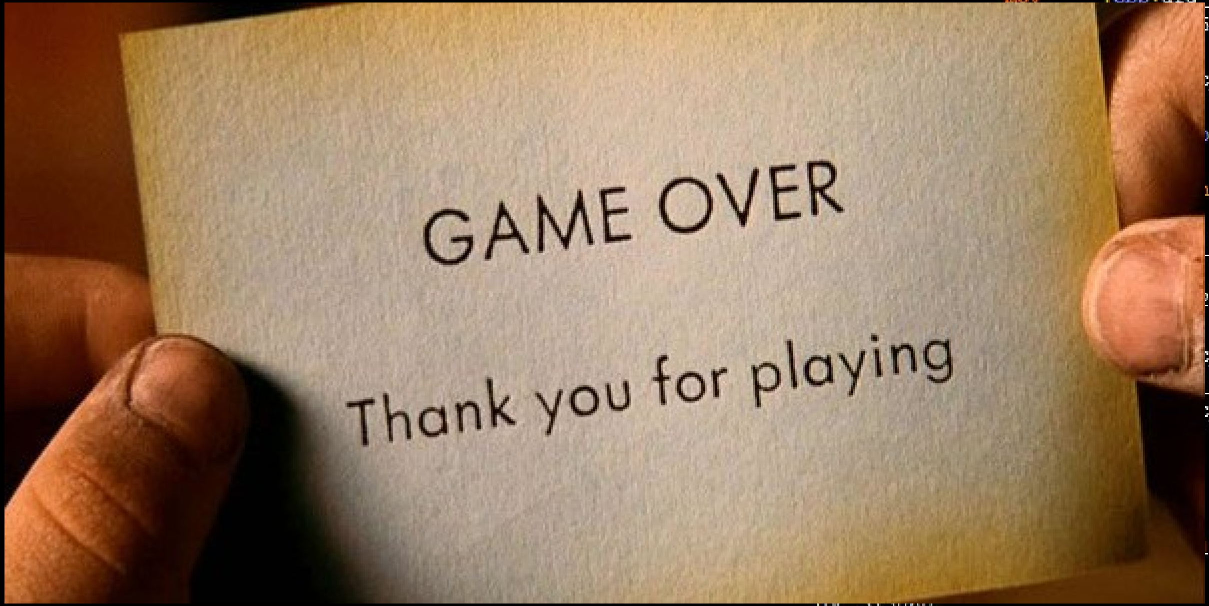
- bootldr also exploited and dumped for fun
  - Not updateable anyway, so it doesn’t matter much



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                j[illegible]  short loc_31[illegible]

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    [illegible]
                call    sub_3141[illegible]

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

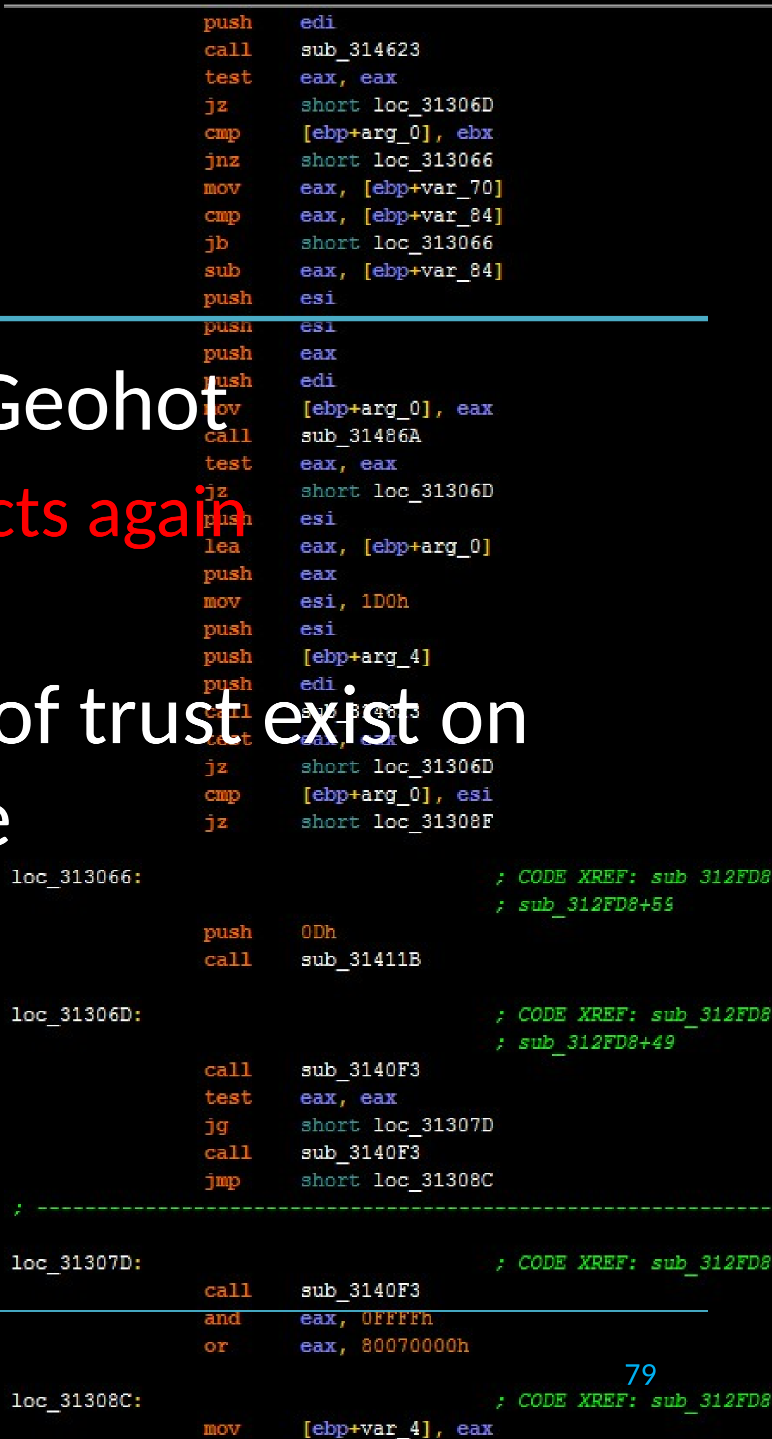


```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                              5A

                              :_31306D

                              )+arg_0]

                              1

                              _4]

                              :3

                              :_31306D
                              _0], esi
                              :_31308F

                                         ; CODE XREF: sub_312FD8
                                         ; sub_312FD8+55

                              B

loc_31306D:                              ; CODE XREF: sub_312FD8
                                         ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                              ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                              ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```



PS3 Aftermath

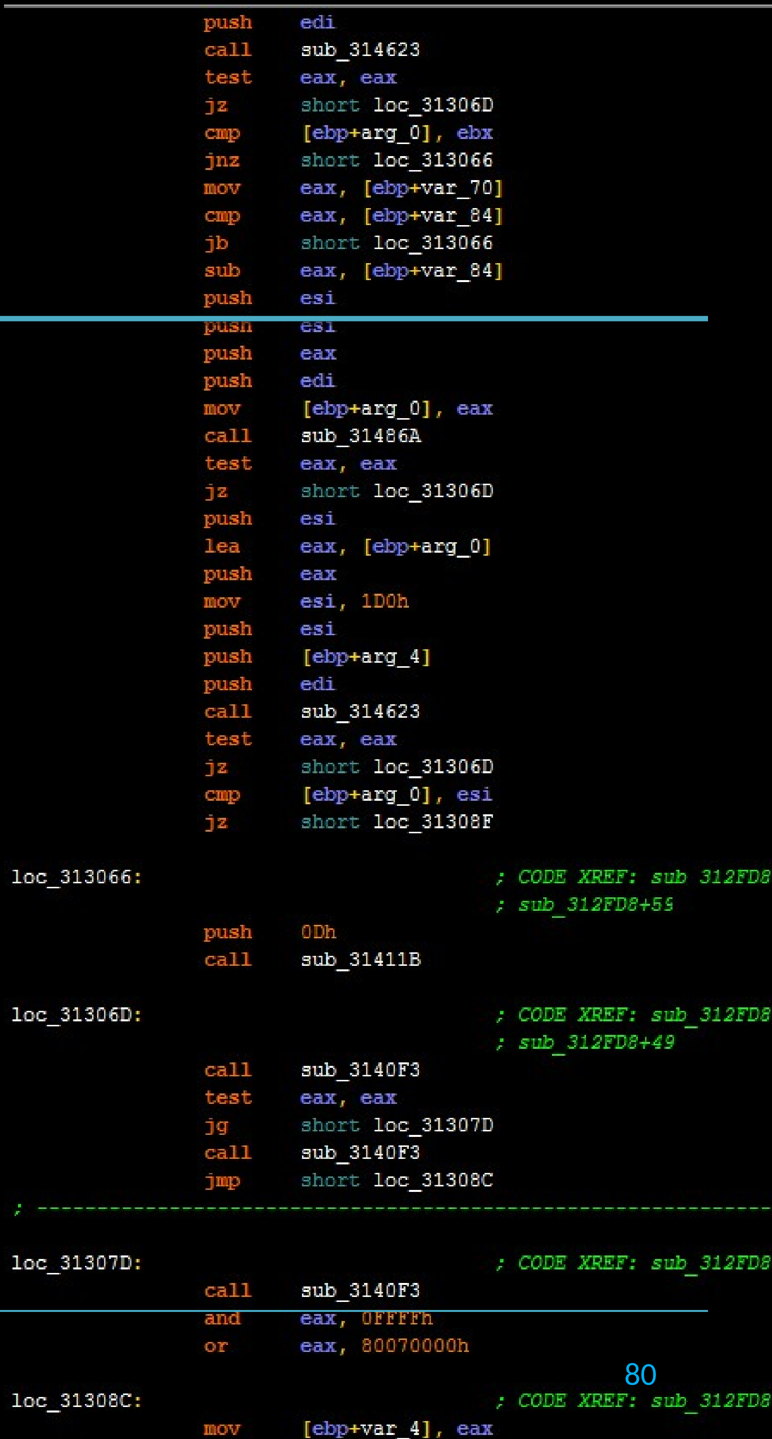
- Sony drops lawsuit against Geohot
  - Must never hack Sony products again
- No more updateable seeds of trust exist on the PS3 that Sony can utilize
  - PS3 totally broken



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    [illegible]
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

Lecture Overview

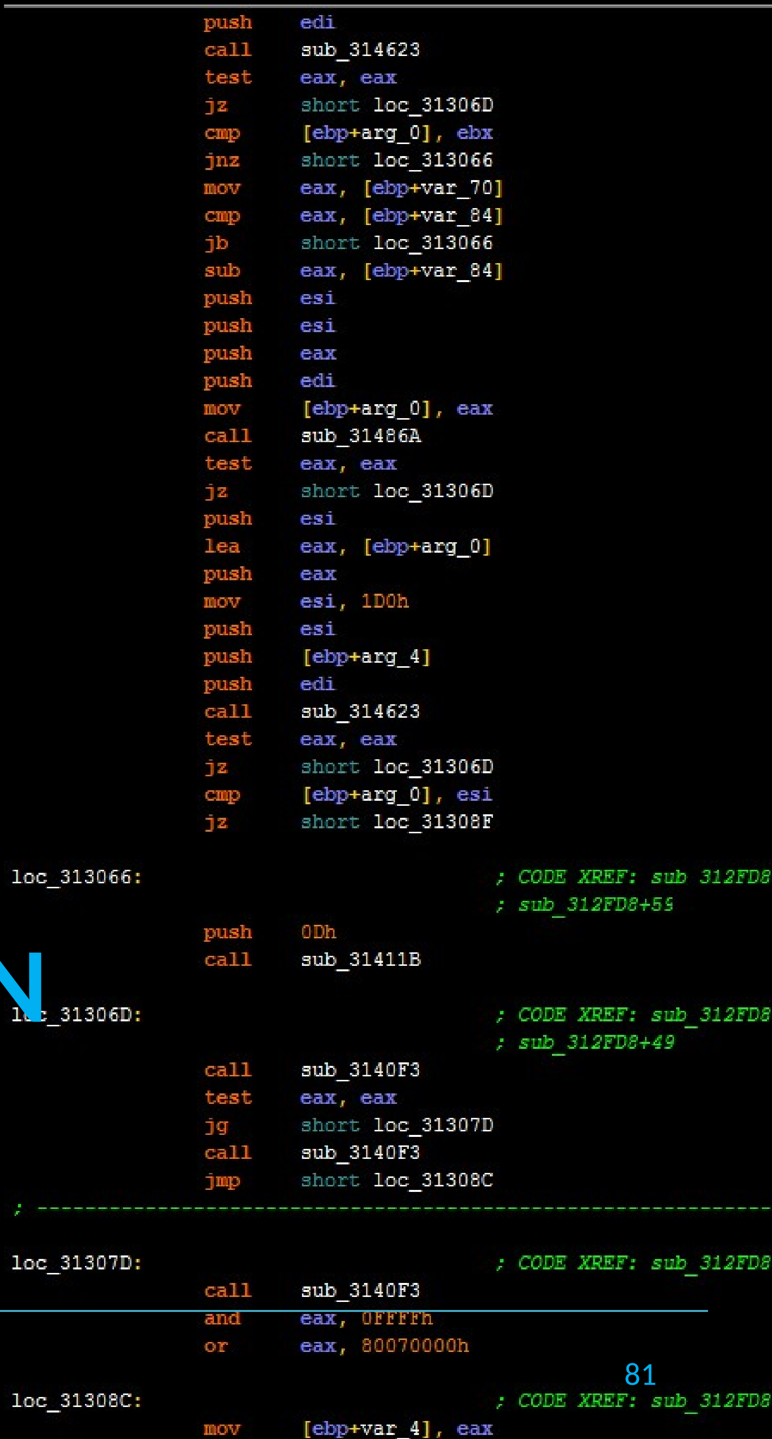
- Secure Systems & Patch Sets
  - OpenBSD
  - SELinux
  - Grsecurity
- Owning Game Consoles
  - Xbox 360
  - Nintendo 3DS
  - PS3
- Current Generation



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

CURRENT GENERATION

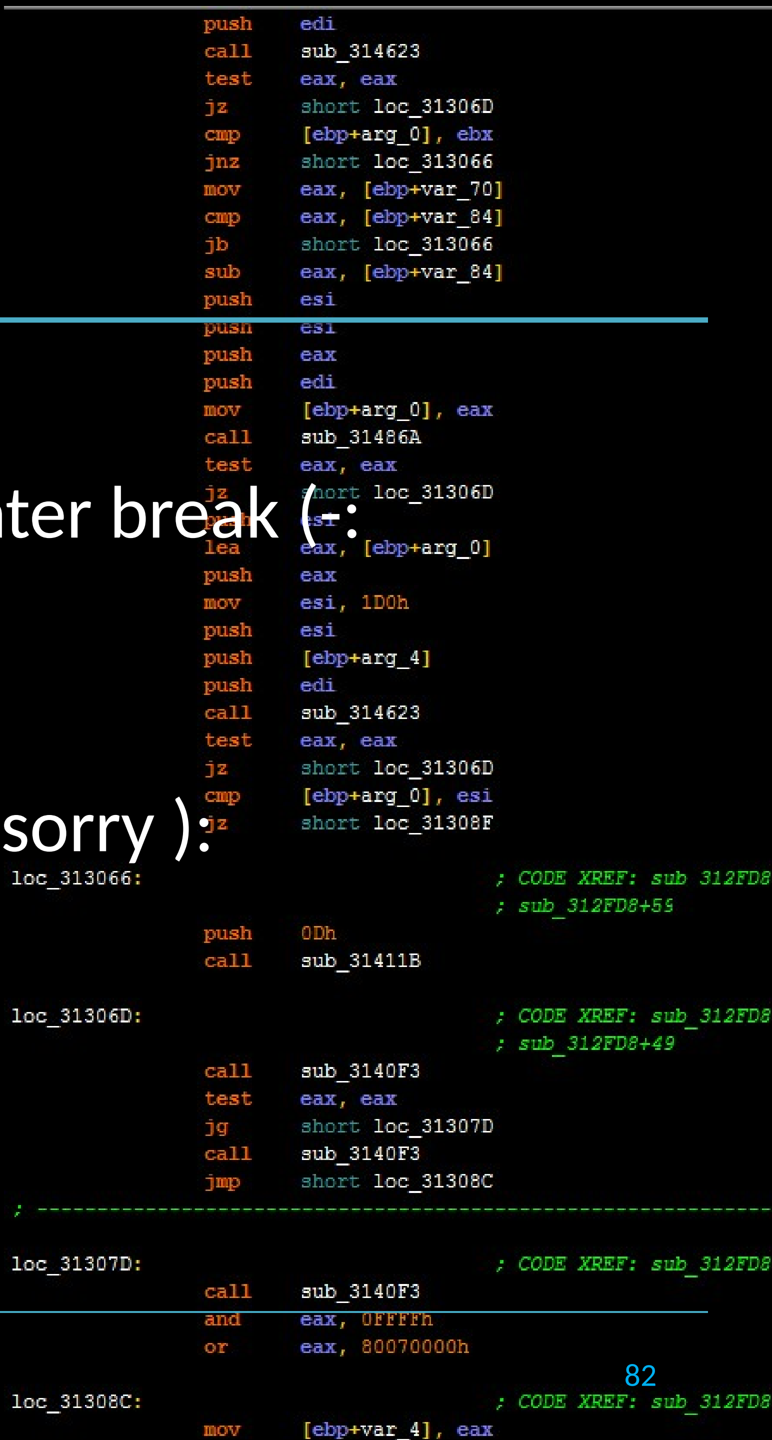
A peek at the current generation of consoles



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+59
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

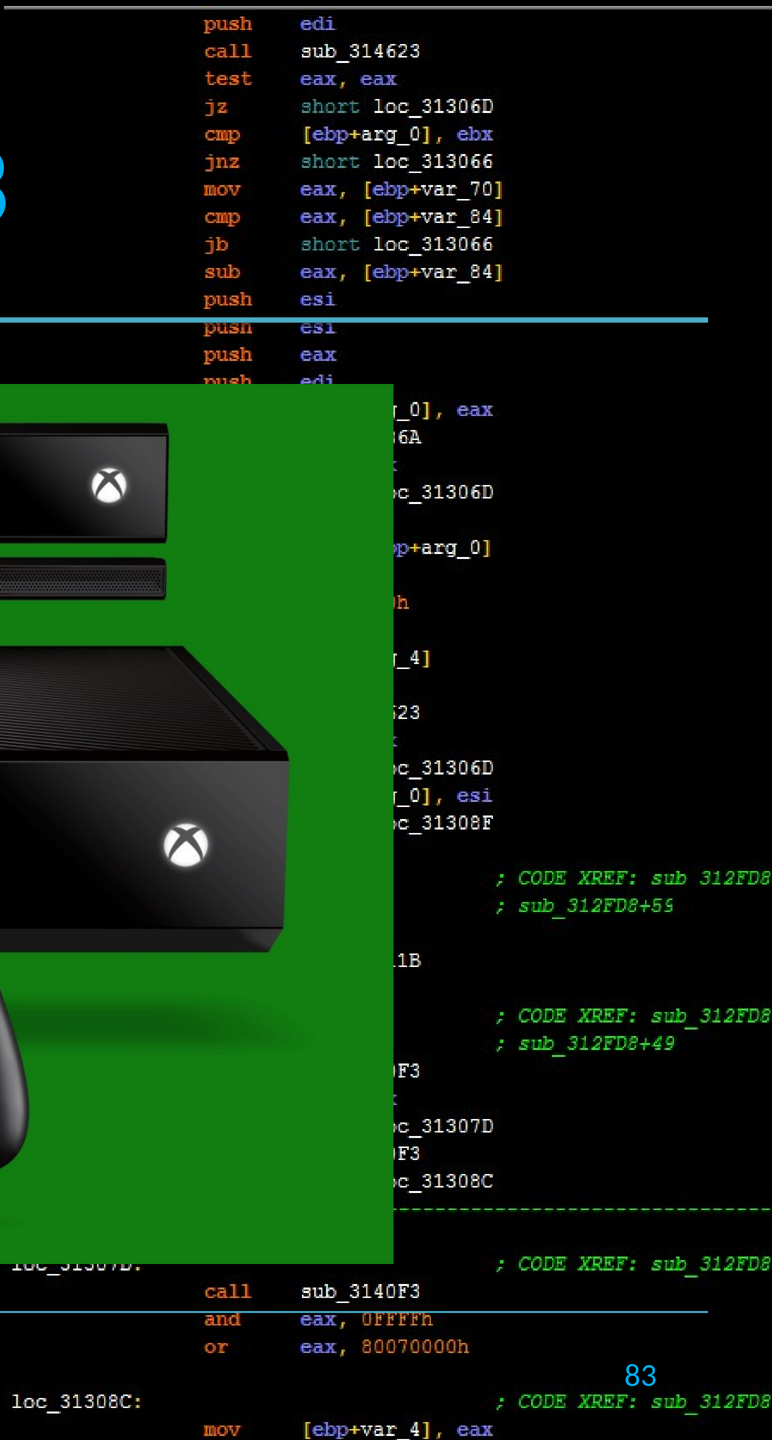
Current Generation

- Xbox One
  - I did some reversing over winter break (-:
- PS4
  - I don't know as much about, sorry):



```
            push    edi
            call    sub_314623
            test    eax, eax
            jz      short loc_31306D
            cmp     [ebp+arg_0], ebx
            jnz     short loc_313066
            mov     eax, [ebp+var_70]
            cmp     eax, [ebp+var_84]
            jb      short loc_313066
            sub     eax, [ebp+var_84]
            push    esi
            push    esi
            push    eax
            push    edi
            mov     [ebp+arg_0], eax
            call    sub_31486A
            test    eax, eax
            jz      short loc_31306D
            push    esi
            lea     eax, [ebp+arg_0]
            push    eax
            mov     esi, 1D0h
            push    esi
            push    [ebp+arg_4]
            push    edi
            call    sub_314623
            test    eax, eax
            jz      short loc_31306D
            cmp     [ebp+arg_0], esi
            jz      short loc_31308F

loc_313066:                                 ; CODE XREF: sub_312FD8
                                            ; sub_312FD8+55
            push    0Dh
            call    sub_31411B

loc_31306D:                                 ; CODE XREF: sub_312FD8
                                            ; sub_312FD8+49
            call    sub_3140F3
            test    eax, eax
            jg      short loc_31307D
            call    sub_3140F3
            jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                                 ; CODE XREF: sub_312FD8
            call    sub_3140F3
            and     eax, 0FFFFh
            or      eax, 80070000h

loc_31308C:                                 ; CODE XREF: sub_312FD8
            mov     [ebp+var_4], eax
```

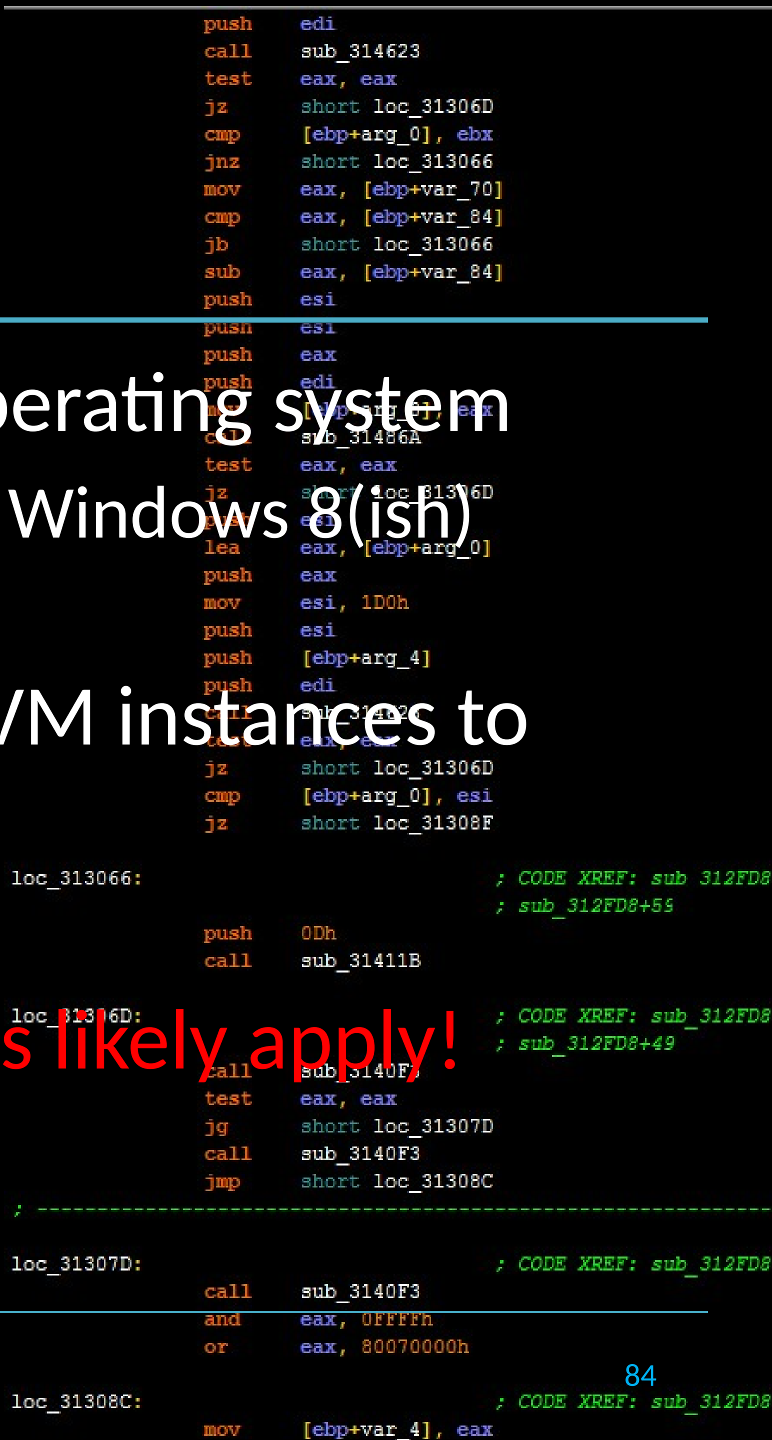
Xbox One – Nov. 2013



```
        push    edi
        call    sub_314623
        test    eax, eax
        jz      short loc_31306D
        cmp     [ebp+arg_0], ebx
        jnz     short loc_313066
        mov     eax, [ebp+var_70]
        cmp     eax, [ebp+var_84]
        jb      short loc_313066
        sub     eax, [ebp+var_84]
        push    esi
        push    esi
        push    eax
        push    edi
                   _0], eax
                   6A

                   c_31306D

                   p+arg_0]

                   h

                   _4]

                   23

                   c_31306D
                   _0], esi
                   c_31308F

                                 ; CODE XREF: sub_312FD8
                                 ; sub_312FD8+55

                   1B

                                 ; CODE XREF: sub_312FD8
                                 ; sub_312FD8+49
                   F3

                   c_31307D
                   F3
                   c_31308C
                   ----------------------------------

loc_31307D:                      ; CODE XREF: sub_312FD8
        call    sub_3140F3
        and     eax, 0FFFFh
        or      eax, 80070000h

loc_31308C:                      ; CODE XREF: sub_312FD8
        mov     [ebp+var_4], eax
```

Xbox One OS

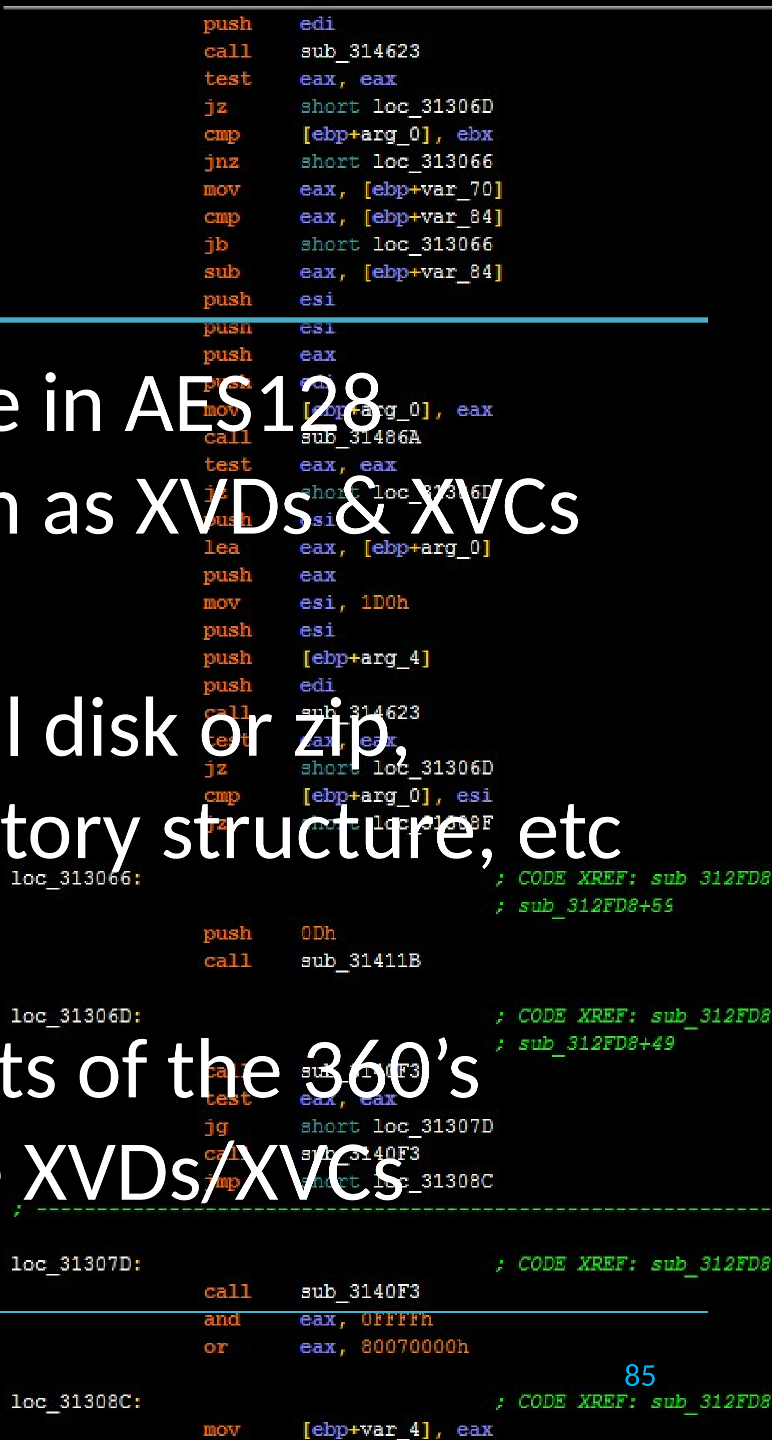
- Ditches the 360’s custom operating system
  - Xbox OS (XOS) is forked from Windows 8(ish)
- Spins up minimal windows VM instances to run your games, apps, etc
- Windows 8/8.1 core OS bugs likely apply!



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_31462[illegible]
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+59
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

Xbox Virtual Disks

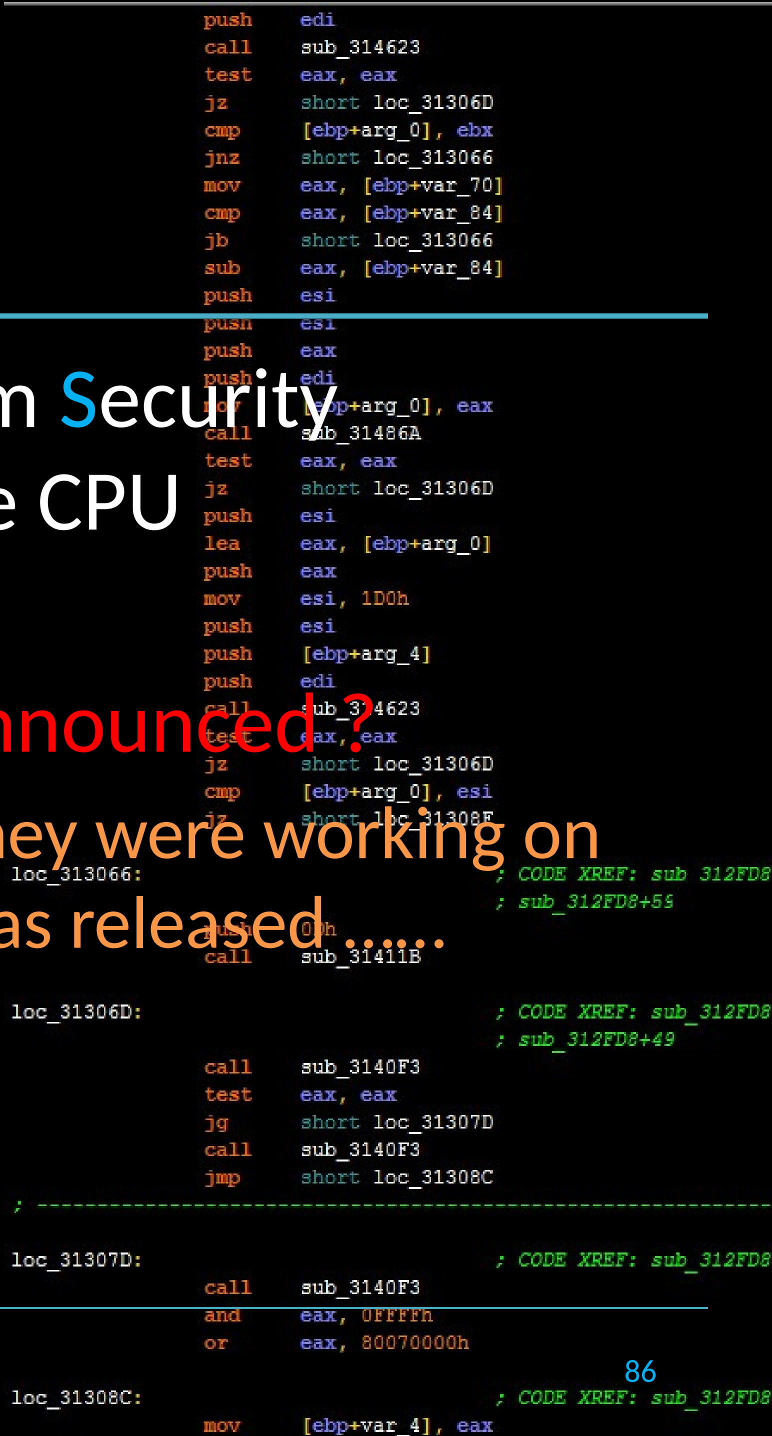
- Starting out, most things are in AES128 encrypted containers known as XVDs & XVCs
- Just like an encrypted virtual disk or zip, contains .exe’s, assets, directory structure, etc
- A lot of the security elements of the 360’s .XEX’s were inherited by the XVDs/XVCs



```
         push    edi
         call    sub_314623
         test    eax, eax
         jz      short loc_31306D
         cmp     [ebp+arg_0], ebx
         jnz     short loc_313066
         mov     eax, [ebp+var_70]
         cmp     eax, [ebp+var_84]
         jb      short loc_313066
         sub     eax, [ebp+var_84]
         push    esi
         push    esi
         push    eax
         push    edi
         mov     [ebp+arg_0], eax
         call    sub_31486A
         test    eax, eax
         jz      short loc_31306D
         push    esi
         lea     eax, [ebp+arg_0]
         push    eax
         mov     esi, 1D0h
         push    esi
         push    [ebp+arg_4]
         push    edi
         call    sub_314623
         test    eax, eax
         jz      short loc_31306D
         cmp     [ebp+arg_0], esi
         jz      short loc_31308F

loc_313066:                              ; CODE XREF: sub_312FD
                                         ; sub_312FD8+55
         push    0Dh
         call    sub_31411B

loc_31306D:                              ; CODE XREF: sub_312FD8
                                         ; sub_312FD8+49
         call    sub_3140F3
         test    eax, eax
         jg      short loc_31307D
         call    sub_3140F3
         jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                              ; CODE XREF: sub_312FD8
         call    sub_3140F3
         and     eax, 0FFFFh
         or      eax, 80070000h

loc_31308C:                              ; CODE XREF: sub_312FD8
         mov     [ebp+var_4], eax
```

Xbox One PSP

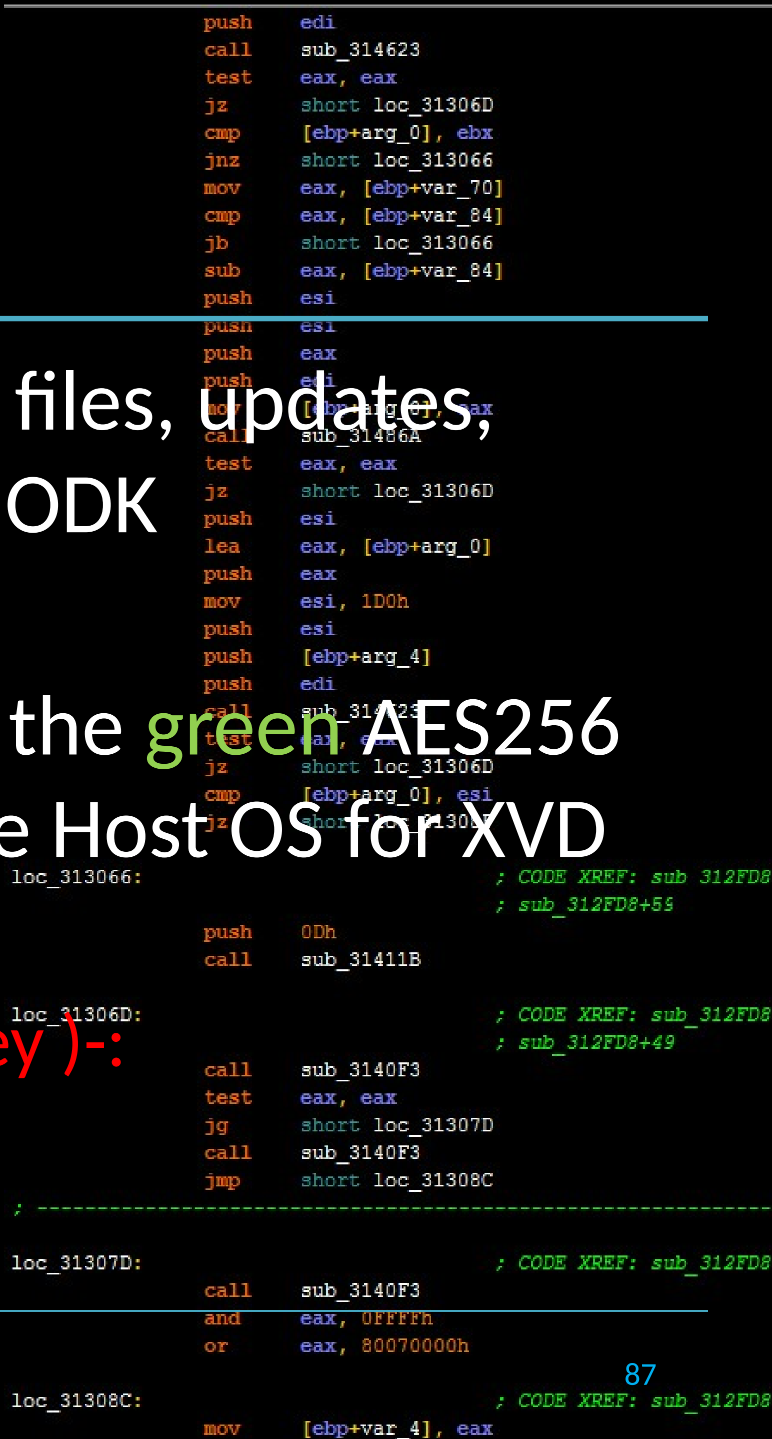
- AMD snuck an ARM Platform Security Processor into the Xbox One CPU
- ? This was never formally announced ?
  - AMD only ever announced they were working on this technology, not that it was released ......



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                                  ; CODE XREF: sub_312FD8
                                             ; sub_312FD8+55
                push    0?h
                call    sub_31411B

loc_31306D:                                  ; CODE XREF: sub_312FD8
                                             ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                                  ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                                  ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

Xbox One PSP

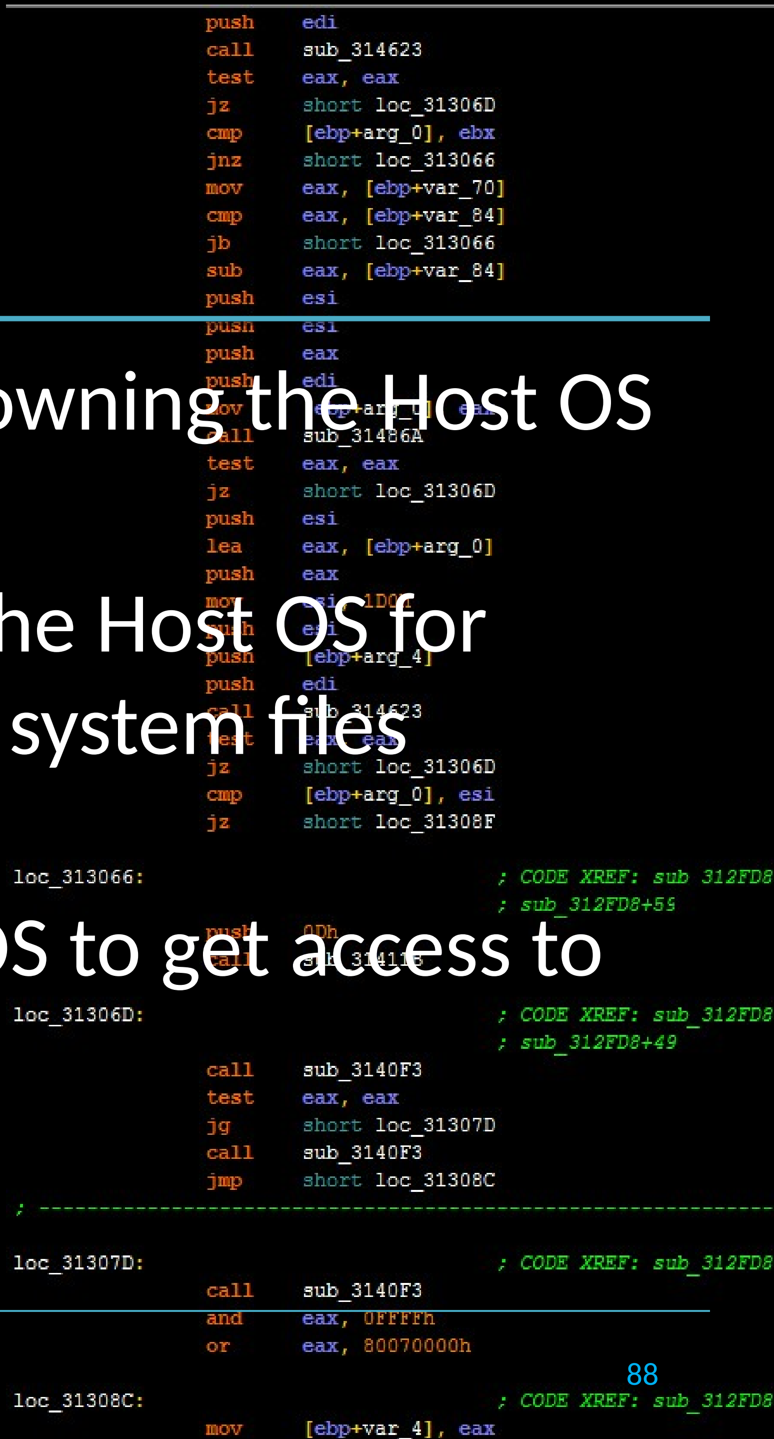
- Nobody can decrypt system files, updates, without the ‘green’ AES256 ODK
- Host OS queries the PSP for the green AES256 ODK key, PSP passes it to the Host OS for XVD decryption
  - It would be nice to get this key)-:



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31306[illegible]

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+59
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

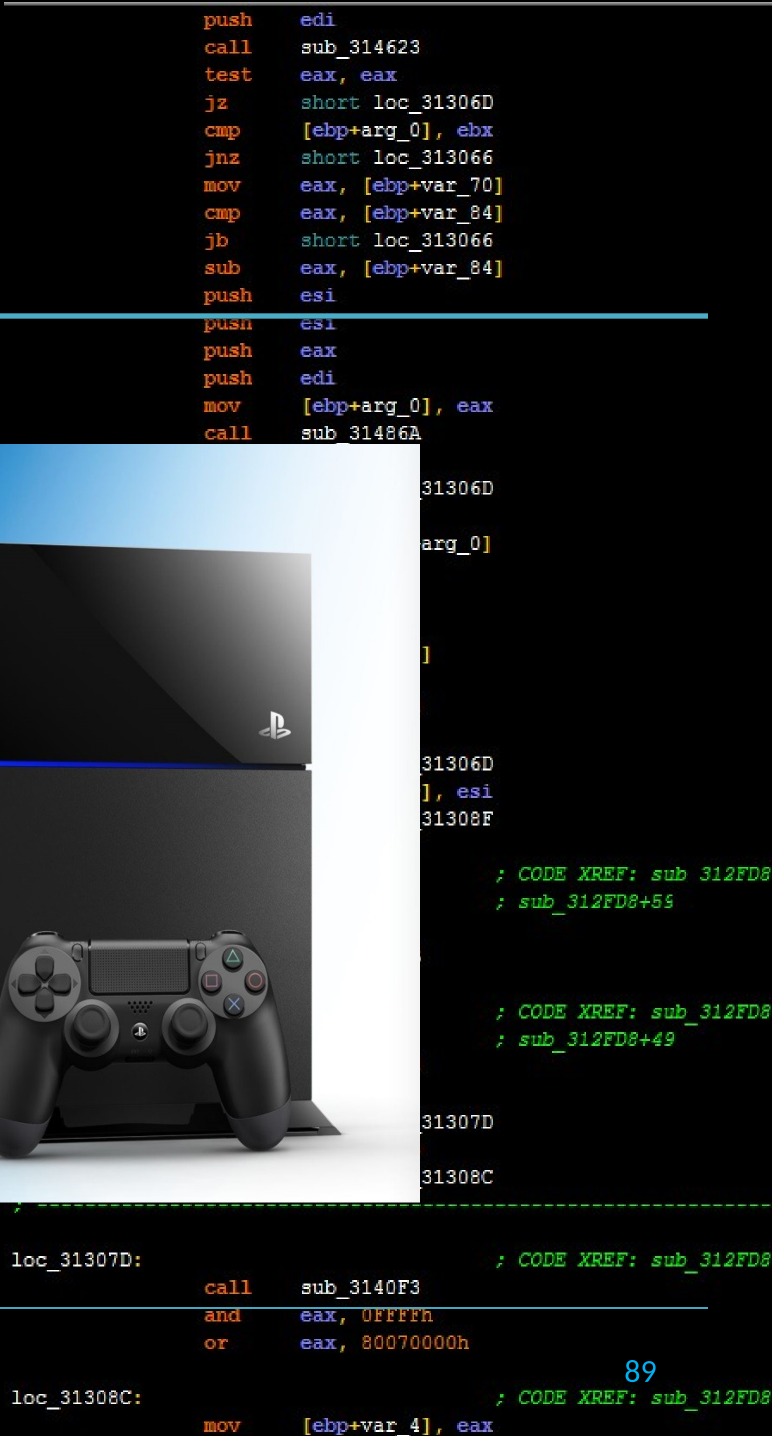
Xbox One Host OS

- Owning the system means owning the Host OS
- You can’t effectively comb the Host OS for bugs if you can’t decrypt its system files
- You need to own the Host OS to get access to the keys used to decrypt it
  - <span style="color:red">– Chicken & the egg problem</span>



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub 312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

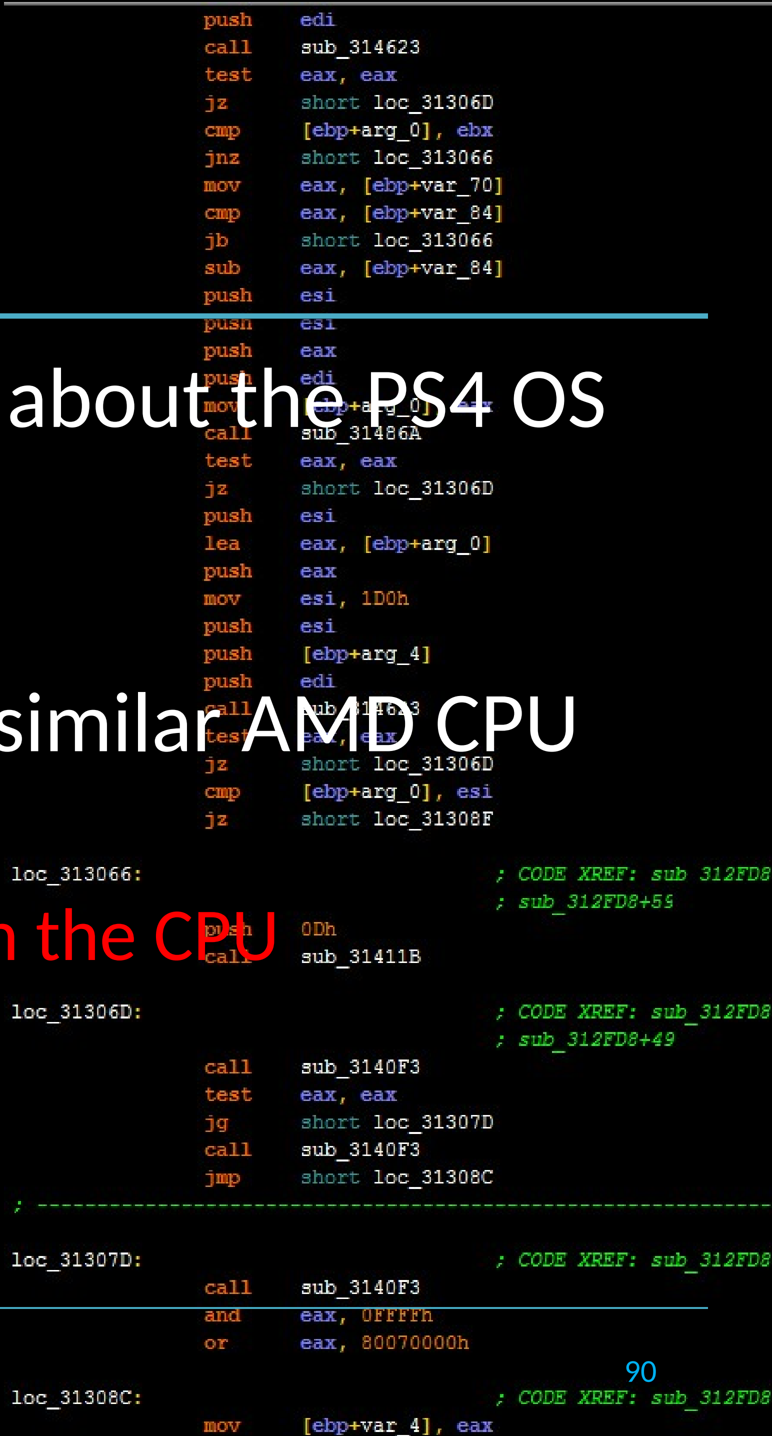
PS4 – Nov. 2013



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A

                                31306D

                                arg_0]



                                ]



                                31306D
                                ], esi
                                31308F

                                        ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55



                                        ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49



                                31307D

                                31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

PS4 Details

- I really don’t know as much about the PS4 OS or its security features
- I do know that it has a very similar AMD CPU as the Xbox One
  - An ARM PSP is also present in the CPU



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```

References, Readings, Talks

- https://www.youtube.com/watch?v=82vf0JQS1Sk
- http://www.securityfocus.com/archive/1/461489
- https://www.youtube.com/watch?v=XtDTNnEvlf8
- https://www.youtube.com/watch?v=uxjpmc8ZIxM
- http://beta.ivc.no/wiki/index.php/Xbox_360_King_Kong_Shader_Exploit
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- http://pastebin.com/gDLyZ6DU
- http://www.ibm.com/developerworks/power/library/pa-cellsecurity/
- http://www.eurasia.nu/wiki/index.php/PS3_Glitch_Hack
- http://rdist.root.org/2010/01/27/how-the-ps3-hypervisor-was-hacked/
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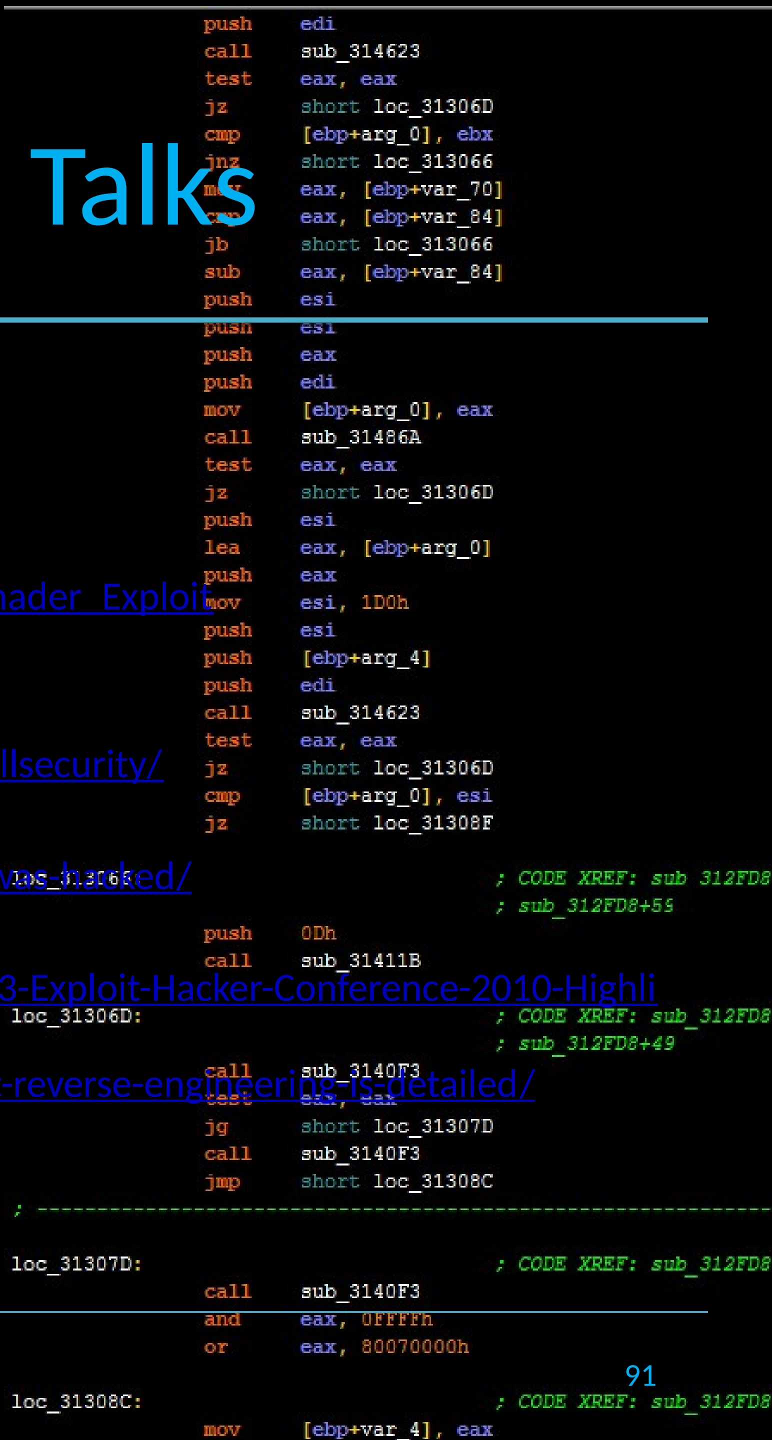
- http://www.ps3news.com/PS3-Hacks/Fail0verflow-27C3-PS3-Exploit-Hacker-Conference-2010-Highlights/
- http://www.ps3news.com/PS3-Dev/ps-jailbreak-ps3-exploit-reverse-engineering-is-detailed/
- http://www.ps3devwiki.com/ps3/Boot_Order
- http://3dbrew.org/



```
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], ebx
                jnz     short loc_313066
                mov     eax, [ebp+var_70]
                cmp     eax, [ebp+var_84]
                jb      short loc_313066
                sub     eax, [ebp+var_84]
                push    esi
                push    esi
                push    eax
                push    edi
                mov     [ebp+arg_0], eax
                call    sub_31486A
                test    eax, eax
                jz      short loc_31306D
                push    esi
                lea     eax, [ebp+arg_0]
                push    eax
                mov     esi, 1D0h
                push    esi
                push    [ebp+arg_4]
                push    edi
                call    sub_314623
                test    eax, eax
                jz      short loc_31306D
                cmp     [ebp+arg_0], esi
                jz      short loc_31308F

loc_313066:                             ; CODE XREF: sub_312FD
                                        ; sub_312FD8+55
                push    0Dh
                call    sub_31411B

loc_31306D:                             ; CODE XREF: sub_312FD8
                                        ; sub_312FD8+49
                call    sub_3140F3
                test    eax, eax
                jg      short loc_31307D
                call    sub_3140F3
                jmp     short loc_31308C
; ---------------------------------------------------------------

loc_31307D:                             ; CODE XREF: sub_312FD8
                call    sub_3140F3
                and     eax, 0FFFFh
                or      eax, 80070000h

loc_31308C:                             ; CODE XREF: sub_312FD8
                mov     [ebp+var_4], eax
```