Win32dd :
Challenges of Windows physical memory acquisition and exploitation

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Who am I?

- Forensics Researcher for the Netherlands Forensics Institute (NFI).
- Microsoft Entreprise Security MVP 2009
- Speaker at various security events, such as PacSec, BlackHat USA, Europol High Tech Crime Meeting etc.
- Some projects that may interest you:
  - HibrShell (http://www.msuiche.net/hibrshell/)
    - Shell for Windows hibernation files manipulation using Microsoft Debugging symbols and based on SandMan Framework.
  - Win32dd (http://win32dd.msuiche.net)
- Blog about reverse engineering : www.msuiche.net

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Talk Outline

- WWWW?
- Memory dump files
- Win32dd & Acquisition
- Exploitation
- Future
- Conclusions

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WWWW

- Why?
  - —For investigation purposes, incident response, malware/rootkit analysis, etc.
- Who?
  - —Incident response engineers, investigators etc..
- When?
  - —As soon as possible
- What?
  - —A copy of the physical memory

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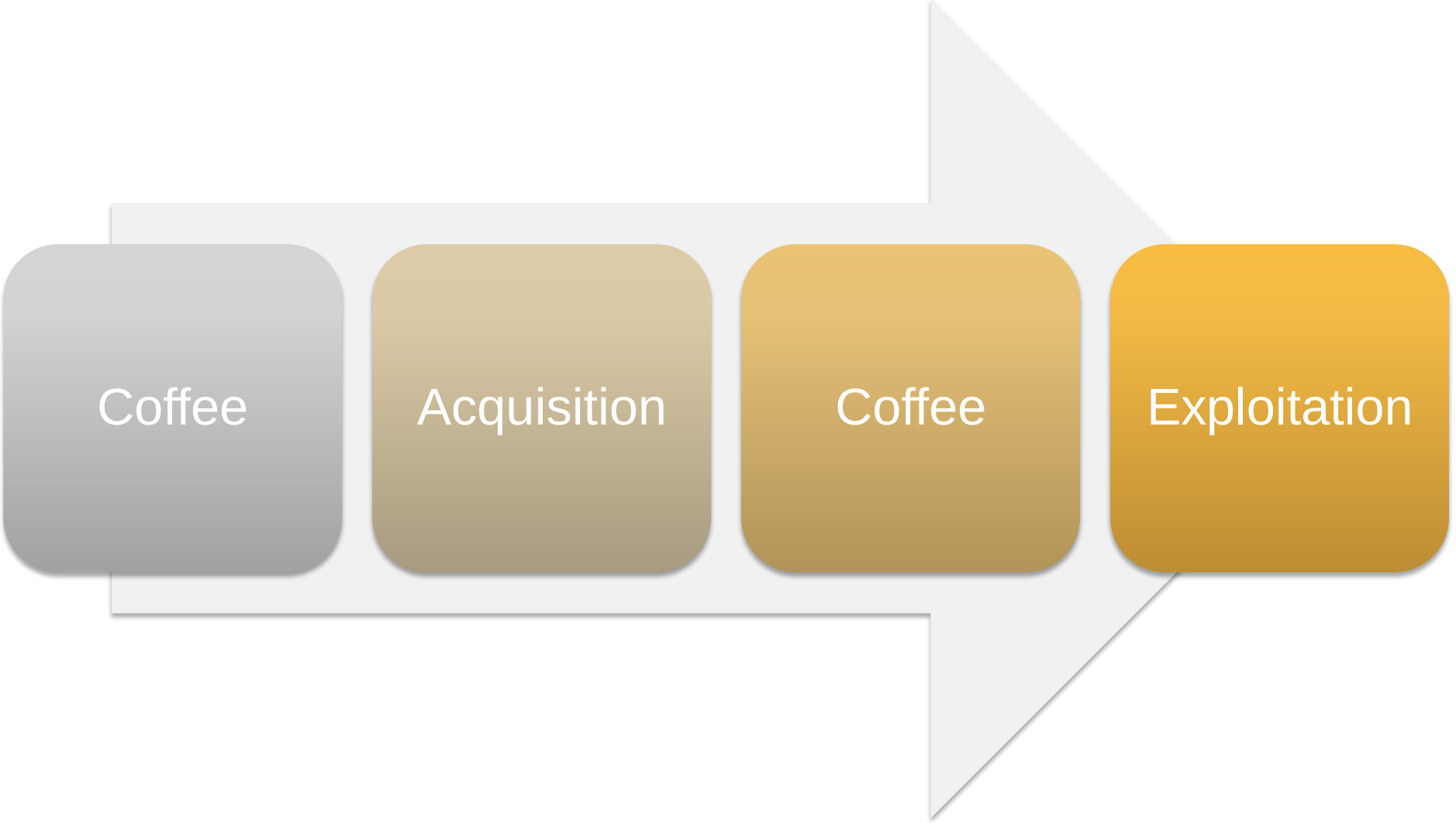
C.A.C.E.



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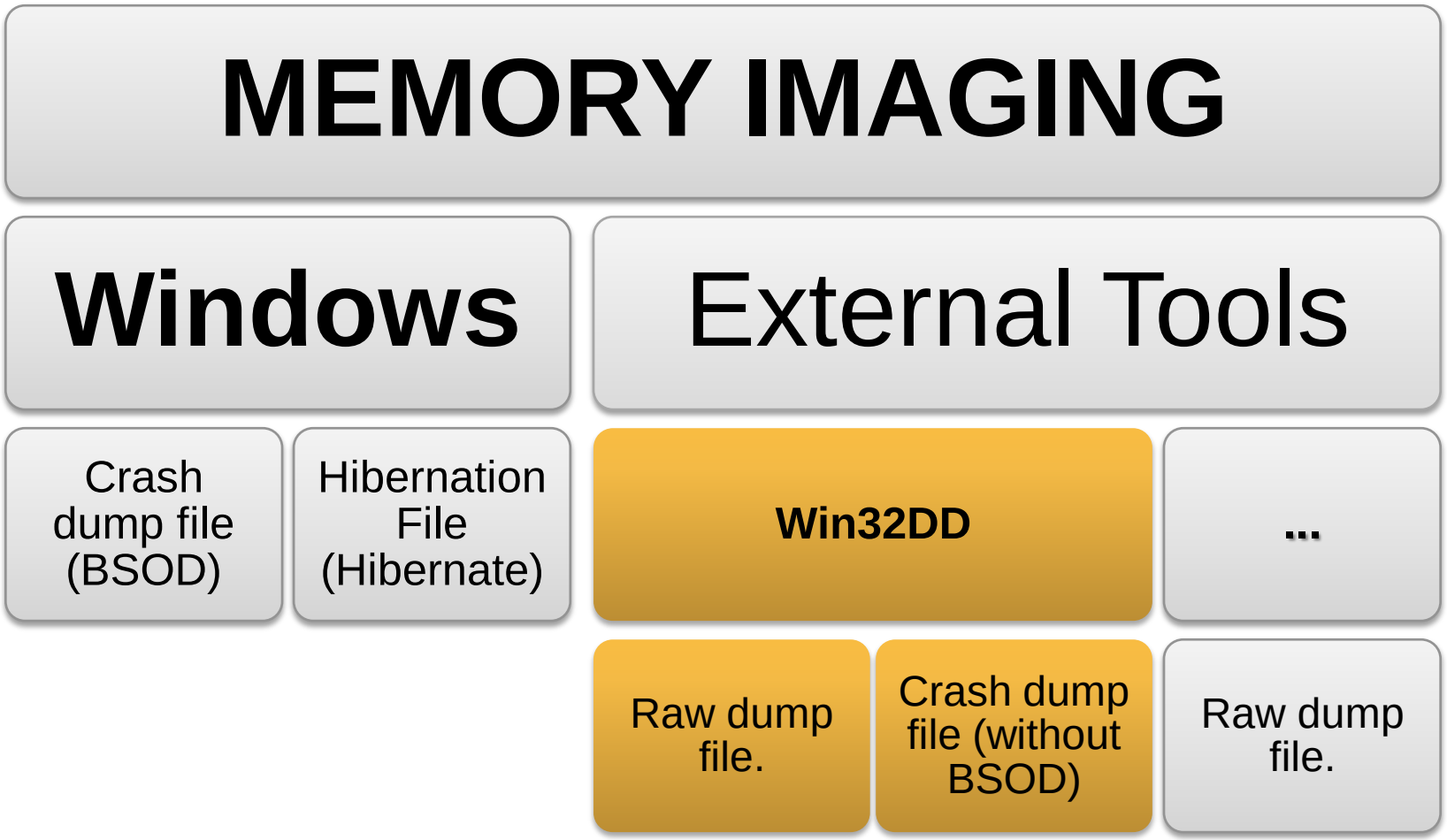
Win32dd & Acquisition



Memory dump files (1/5)

Raw dump file

- Pros: exact, dd-style copy of physical memory
- Cons: dump file does not contain processor state

Memory dump files (2/5)

Crash dump file

- Small memory dump
- Kernel memory dump
- **Complete memory dump**
  - Pros: This is a full memory snapshot of pages used by Windows Memory Manager. This includes both user-land and kernel-land. It means both malware and rootkit analysis can be done. Can be analyzed with WinDbg.
  - Cons: This option is not available on computers that are running a 32-bit operating system and that have 2 gigabytes (GB) or more of RAM according to Microsoft KB 274598.

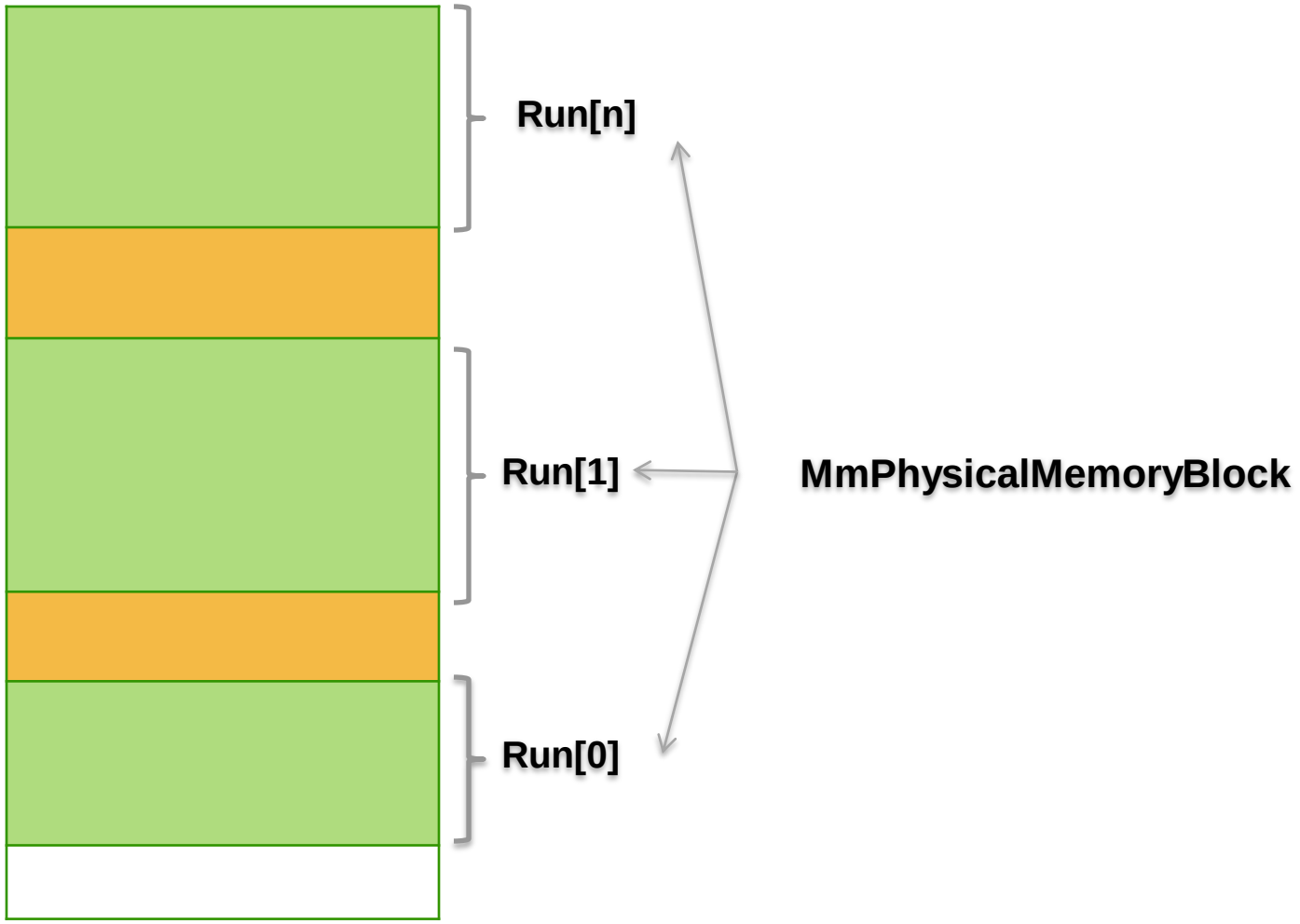
Memory dump files (3/5)

Microsoft Crash Dump Header

```
typedef struct _DUMP_HEADER32 {
    /* 0x000 */ ULONG Signature;
    /* 0x004 */ ULONG ValidDump;
    /* 0x008 */ ULONG MajorVersion;
    /* 0x00C */ ULONG MinorVersion;
    /* 0x010 */ ULONG DirectoryTableBase;
    /* 0x014 */ ULONG PfnDataBase;
    /* 0x018 */ PLIST_ENTRY PsLoadedModuleList;
    /* 0x01C */ PLIST_ENTRY PsActiveProcessHead;
    /* 0x020 */ ULONG MachineImageType;
    /* 0x024 */ ULONG NumberOfProcessors;
    /* 0x028 */ ULONG BugCheckCode;
    /* 0x02C */ ULONG BugCheckParameter1;
    /* 0x030 */ ULONG BugCheckParameter2;
    /* 0x034 */ ULONG BugCheckParameter3;
    /* 0x038 */ ULONG BugCheckParameter4;
    /* 0x03C */ UCHAR VersionUser[32];
    /* 0x05C */ UCHAR PaeEnabled;

    /* 0x05d */ UCHAR KdSecondaryVersion;
    /* 0x05e */ UCHAR Spare3[2];
    /* 0x060 */ PKDDEBUGGER_DATA64 KdDebuggerDataBlock;
    union {
        /* 0x064 */ PHYSICAL_MEMORY_DESCRIPTOR32
PhysicalMemoryBlock;
        /* 0x064 */ UCHAR PhysicalMemoryBlockBuffer[700];
    }
    union {
        /* 0x320 */ CONTEXT Context;
        /* 0x320 */ UCHAR ContextRecord[120];
    }
    /* 0x7d0 */ EXCEPTION_RECORD32 Exception;
    /* 0x820 */ UCHAR Comment[128];
    /* 0x8a0 */ UCHAR _reserved0[1768];
    /* 0xf88 */ ULONG DumpType;
    /* 0xf8c */ ULONG MiniDumpFields;
    /* 0xf90 */ ULONG SecondaryDataState;
    /* 0xf94 */ ULONG ProductType;
    /* 0xf98 */ ULONG SuiteMask;
    /* 0xf9c */ ULONG WriterStatus;
    /* 0xfa0 */ LARGE_INTEGER RequiredDumpSpace;
    /* 0xfa8 */ UCHAR _reserved2[16];
    /* 0xfb8 */ LARGE_INTEGER SystemUpTime;
    /* 0xfc0 */ LARGE_INTEGER SystemTime;
    /* 0xfc8 */ UCHAR _reserved3[56];
} DUMP_HEADER32, *PDUMP_HEADER32;
```

Memory dump files (4/5)



Physical memory ranges defined by Windows memory manager.

Memory dump files (5/5)

Microsoft Crash Dump Header

```
PHYSICAL_MEMORY_DESCRIPTOR32 PhysicalMemoryBlock;


typedef struct _PHYSICAL_MEMORY_DESCRIPTOR
{
     ULONG NumberOfRuns;
     ULONG NumberOfPages;
     PHYSICAL_MEMORY_RUN Run[1];
} PHYSICAL_MEMORY_DESCRIPTOR, *PPHYSICAL_MEMORY_DESCRIPTOR;

typedef struct _PHYSICAL_MEMORY_RUN
{
     ULONG BasePage;
     ULONG PageCount;
} PHYSICAL_MEMORY_RUN, *PPHYSICAL_MEMORY_RUN;
```

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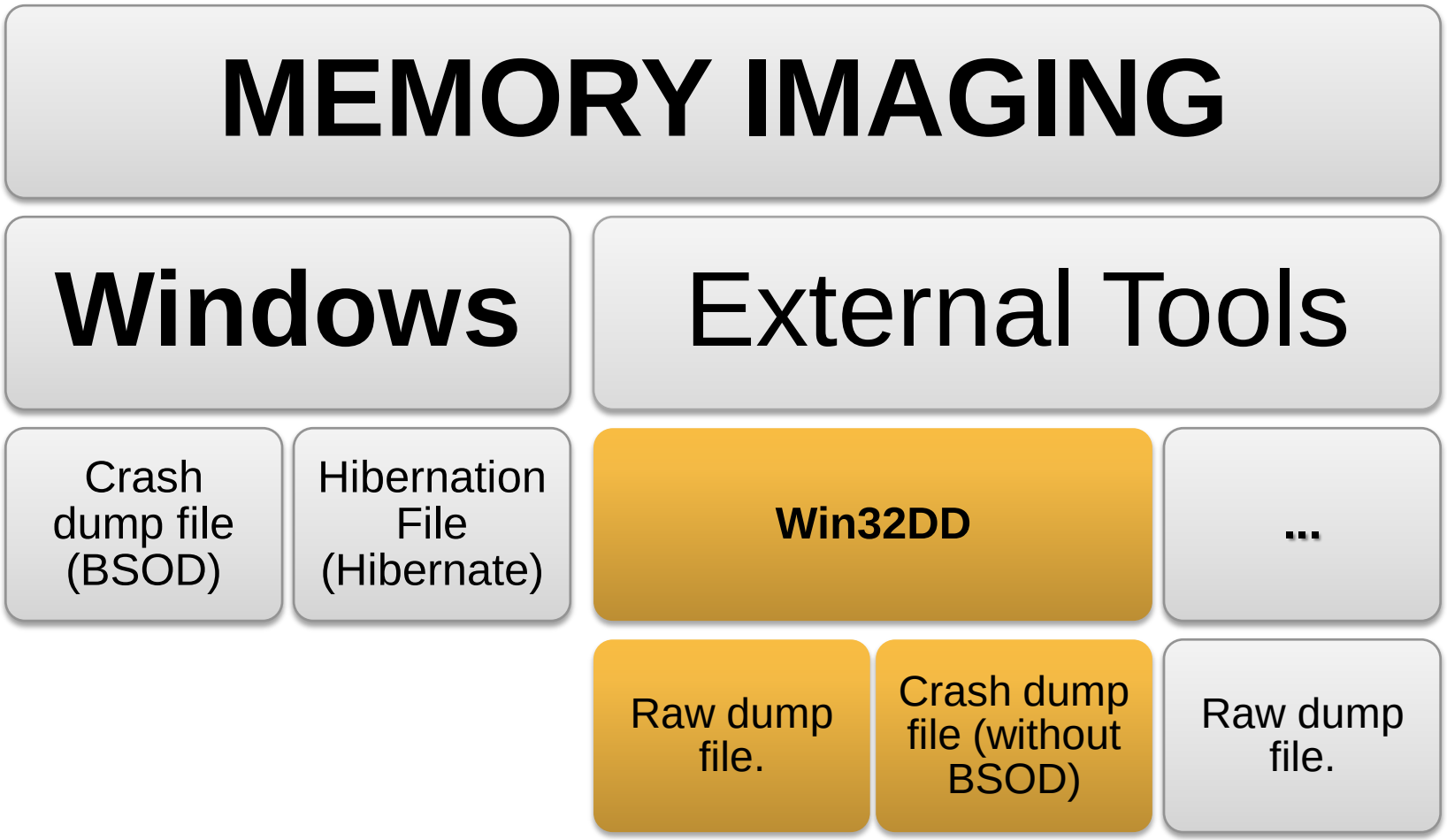
Win32dd & Acquisition



DEMO #1: ACQUISITION

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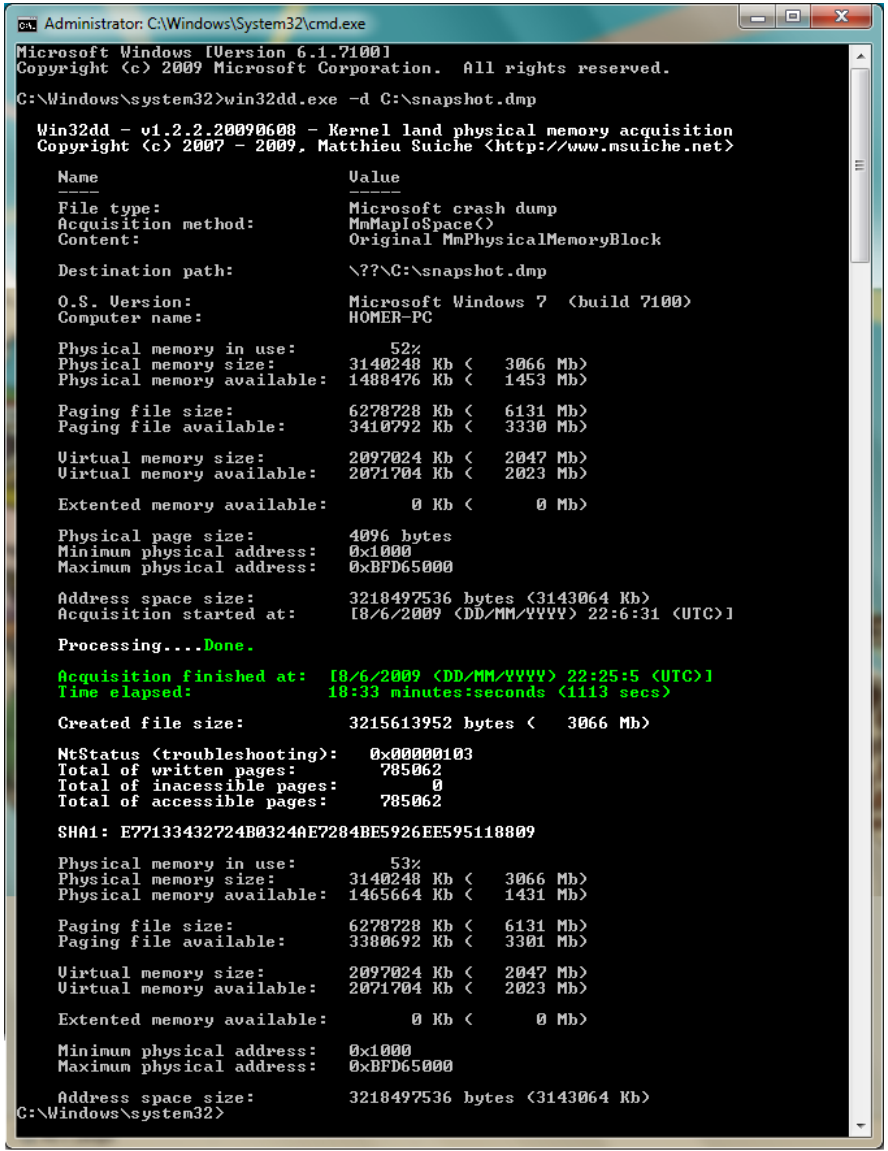
Win32dd & Acquisition



Win32dd and Acquisition

- Initial reason to create win32dd was because of user-land restriction access to \\Device\\PhysicalMemory since Windows 2003 SP1.
  - That's why win32dd is kernel-land based and requires Administrator privileges.
  - … a tool like ShellRunas or Runas, to elevate privilege is also very useful to run win32dd.
- Goal of win32dd is to provide a small, useful swissknife for Windows memory analysis.
  - That's why multiple formats are supported.
  - That's why multiple technical options are provided.
  - SHA1 Hashing

Acquisition

RAW MEMORY DUMP

Win32dd & Acquisition

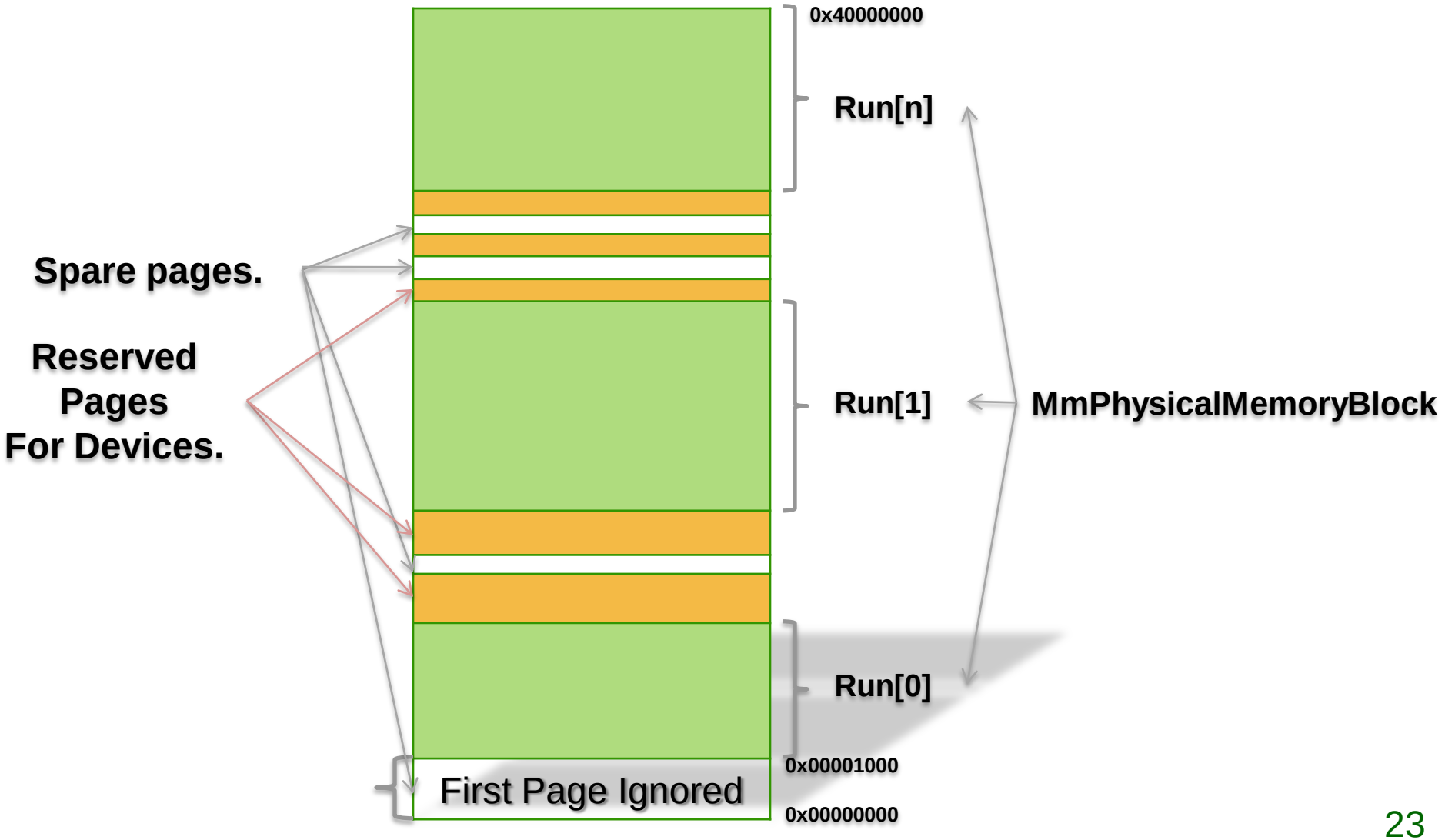
- Two ways provided to access to the physical memory through *–t argument.*
  - — \\Device\\PhysicalMemory object
    - Level 0 - Used by default
  - — MmMapIoSpace() mapping function.
    - Level 1 – *win32dd.exe –l 1 dest_file.bin*
- These levels only apply for the raw dumping.

- This dumps the whole processor view, not just the physical pages used by the Windows memory manager (Mm).

Win32dd & Acquisition

- It means output file size will be bigger than physical memory size.
- If physical memory size is 0x40000000 – it doesn't mean highest physical page would be 0x4000.
- Then, we have to determine the size of the physical address space using this formula :
  - (HighestPhysicalPage + 1) * PAGE_SIZE
- Instead of using physical memory size.

Physical Memory Layout



Acquisition

MICROSOFT CRASH MEMORY DUMP

Win32dd & Acquisition

- MmPhysicalMemoryBlock
  - Valid physical memory ranges detected
- Advantages
  - Reports only physical memory used by Windows Memory Manager, and ignores physical address space dedicated to hardware.
- Limitations
  - Skips interesting pages like the first physical page where pre-boot authentification password is present in plaintext. (< Windows Vista SP1)

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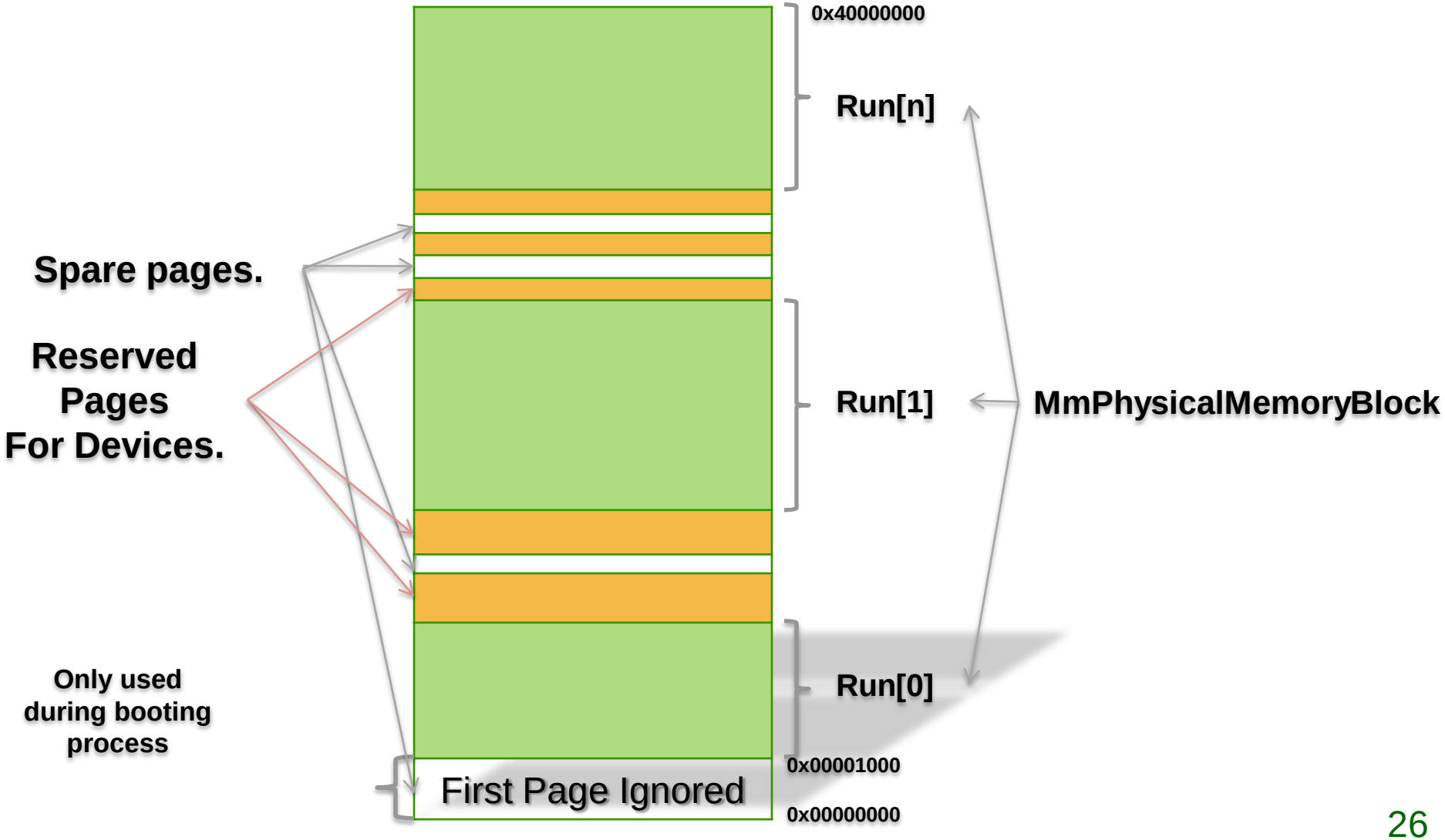
Physical Memory Layout



Win32dd & Acquisition

Win32dd –d option advantages

- Win32dd provide a further option to force to save first physical page.
  - Type 1 – *win32dd -d -t 1 dest_file.dmp*

- Doesn't use Microsoft APIs to generate the Microsoft Crash dump – It means method used by rootkits, like Rustock.C, by registering a callback routine through KeRegisterBugCheckCallback to let the drive cleaning its memory when KeBugCheck happens doesn't affect win32dd.

Win32dd & Acquisition

- User should use the –d option to generate a Microsoft crash dump with Win32dd.
- Two methods for the –d option

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Exploitation

- **#1** Extracting information is the most important part of an investigation.

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    Microsoft

- Microsoft Tools :
  - —WinDbg
  - —Debugging Symbols
  - —PowerDbg (PowerShell library)

- Moreover, WinDbg also has a HUGE community then it’s easier to find resources (scripts, add-ons, books, articles, …)

Exploitation

- **WinDbg** is a multipurpose graphical debugger for Microsoft Windows, distributed on the web by Microsoft. It can be used to debug user mode applications, drivers, and the operating system itself in kernel mode. **WinDbg** also has the ability to automatically load debugging symbol files (e.g., PDB files) from Microsoft servers.

- **Debugging Symbols files** contains information about internal structures (e.g. EPROCESS), unexported symbols and so on.

- **PowerDbg** is a **PowerShell** library that enables you to easily create **PowerShell** scripts that automate the debugging session, interacting with **WinDbg**. You can use **PowerDbg** for Kernel Mode or User Mode, Post-Mortem debugging or Live Debugging and for native or managed code.

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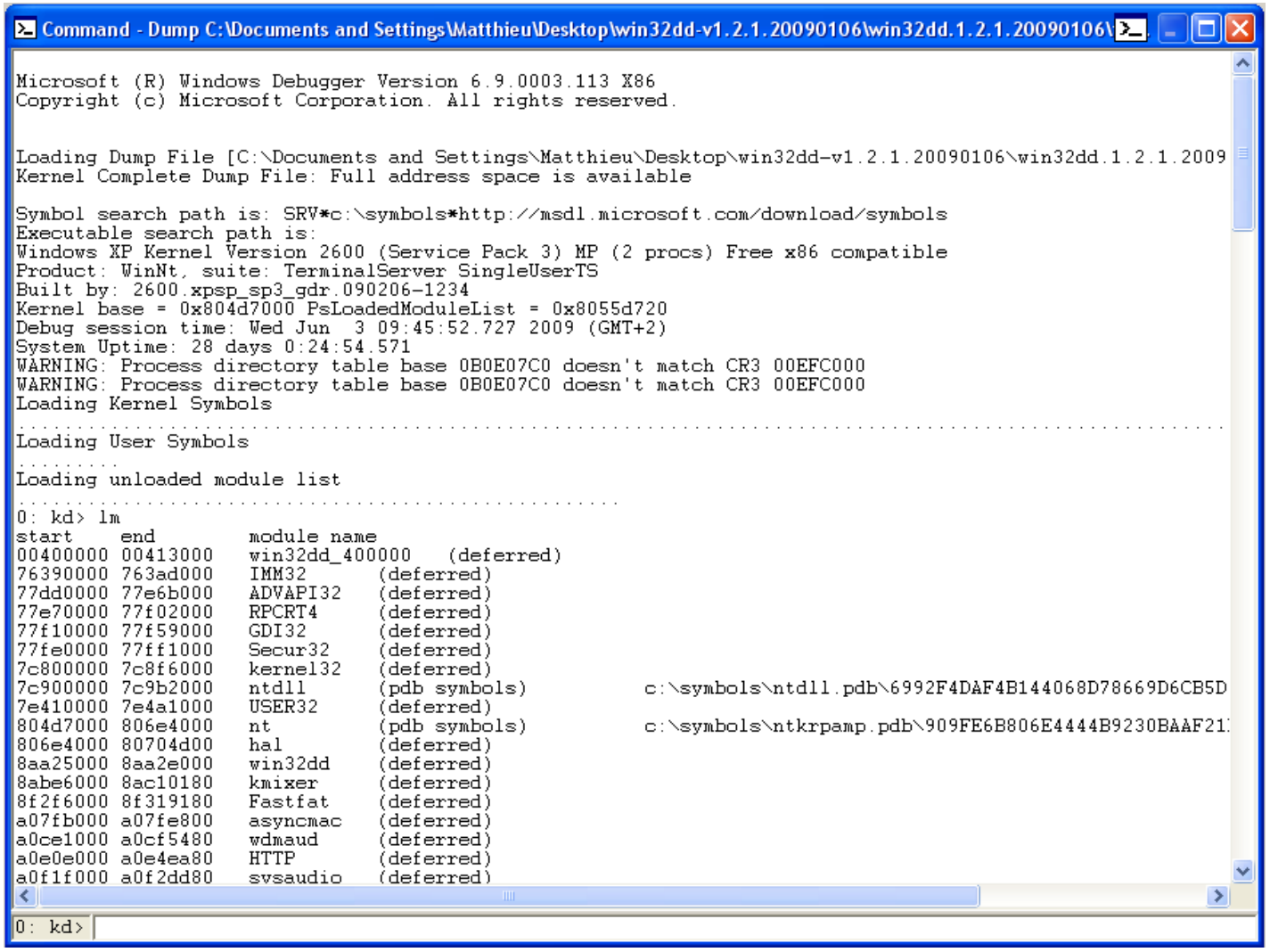
Exploitation

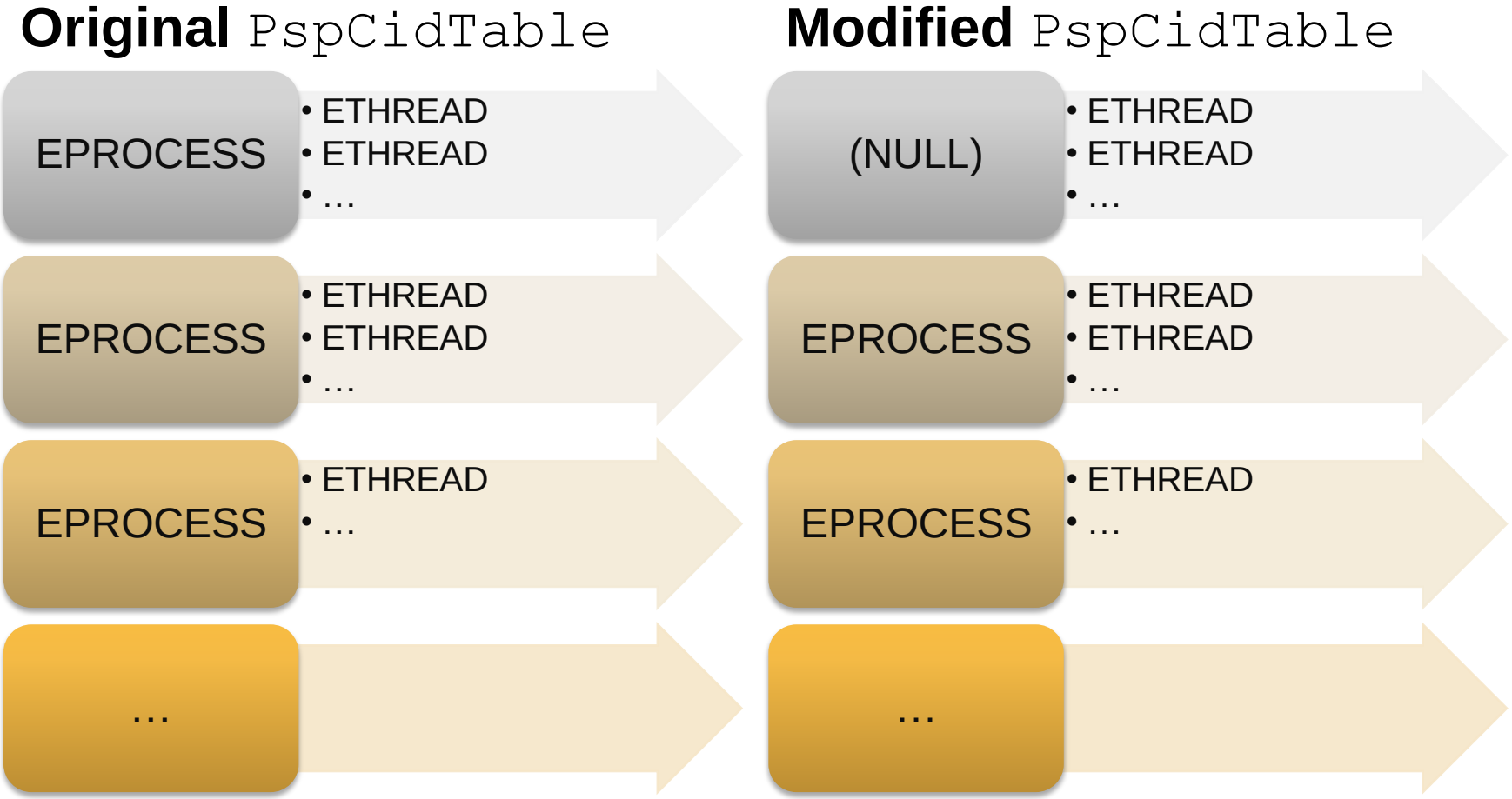


DEMO #1: FUto detection using all these technologies

Futo Mechanism

- Futo is Rootkit designed by Peter Silberman and CHAOS.
- Futo can hide processes using the following scheme
  1. Localize `PspCidTable`
  2. Erase entry pointing to `EPROCESS` which belong to the process
- … but this Table also contains pointers to `ETHREAD`

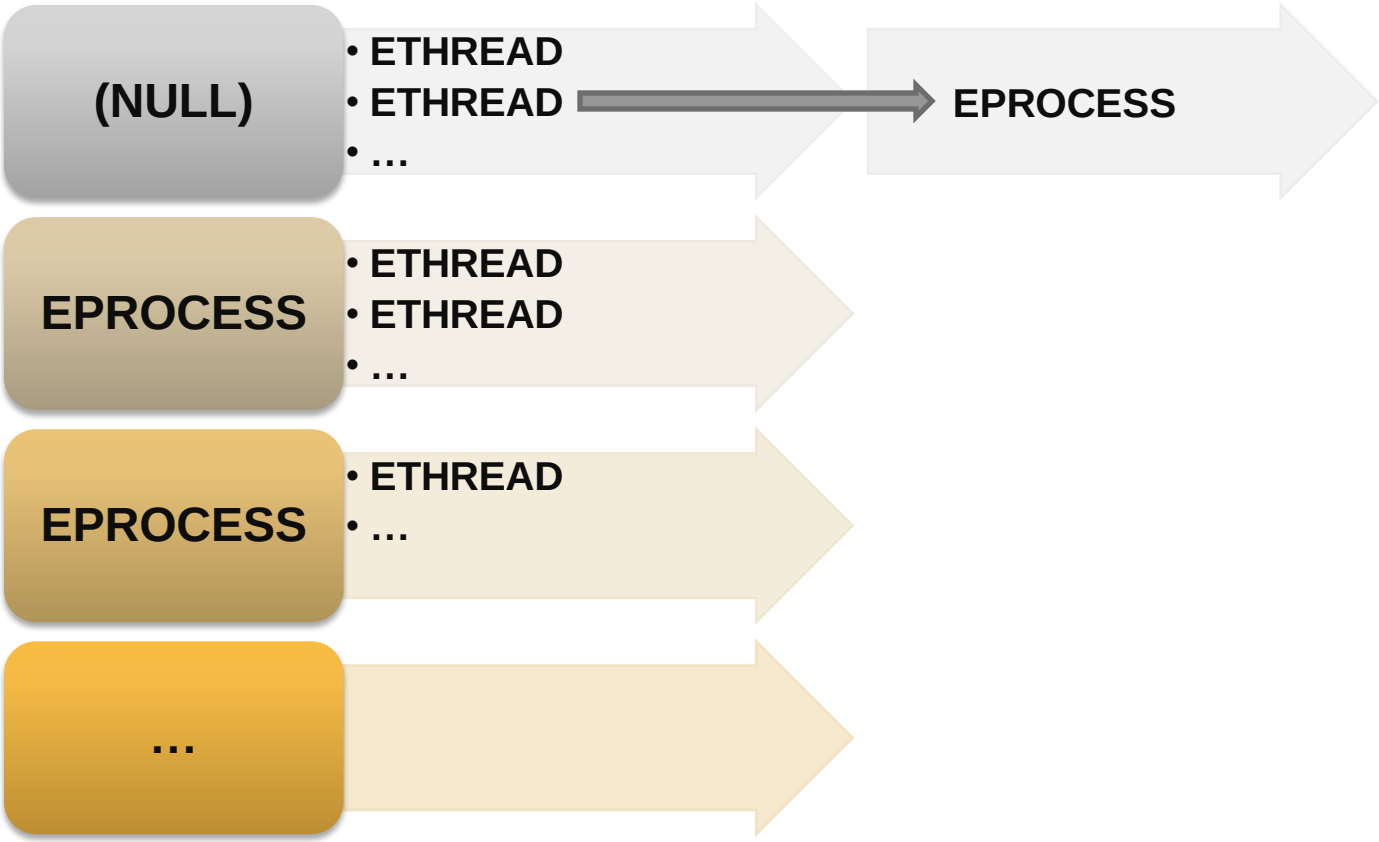
Futo Mechanism



Futo Detection

- Guasconi Vincent designed a method to retrieve hidden processes.
  1. Scan every `PspCidTable` entries
  2. Check if the entry is a `ETHREAD` pointer using `ServiceTable` field
  3. Save `ThreadsProcess` field which is a pointer to its `EPROCESS` root.
  4. Then compare active `EPROCESS` pointers list with retrieved `EPROCESS` pointers list from `ETHREAD` entries.

Futo Detection



FUto.ps1

- PowerShell script
  - Because Python is so 2003, and PowerShell so 2010 ☺
  - Out-GridView command is really nice
- Uses WinDbg + PowerDbg + PowerShell
- Generic because it uses symbols and WinDbg commands
  - No need to reinvent the wheel

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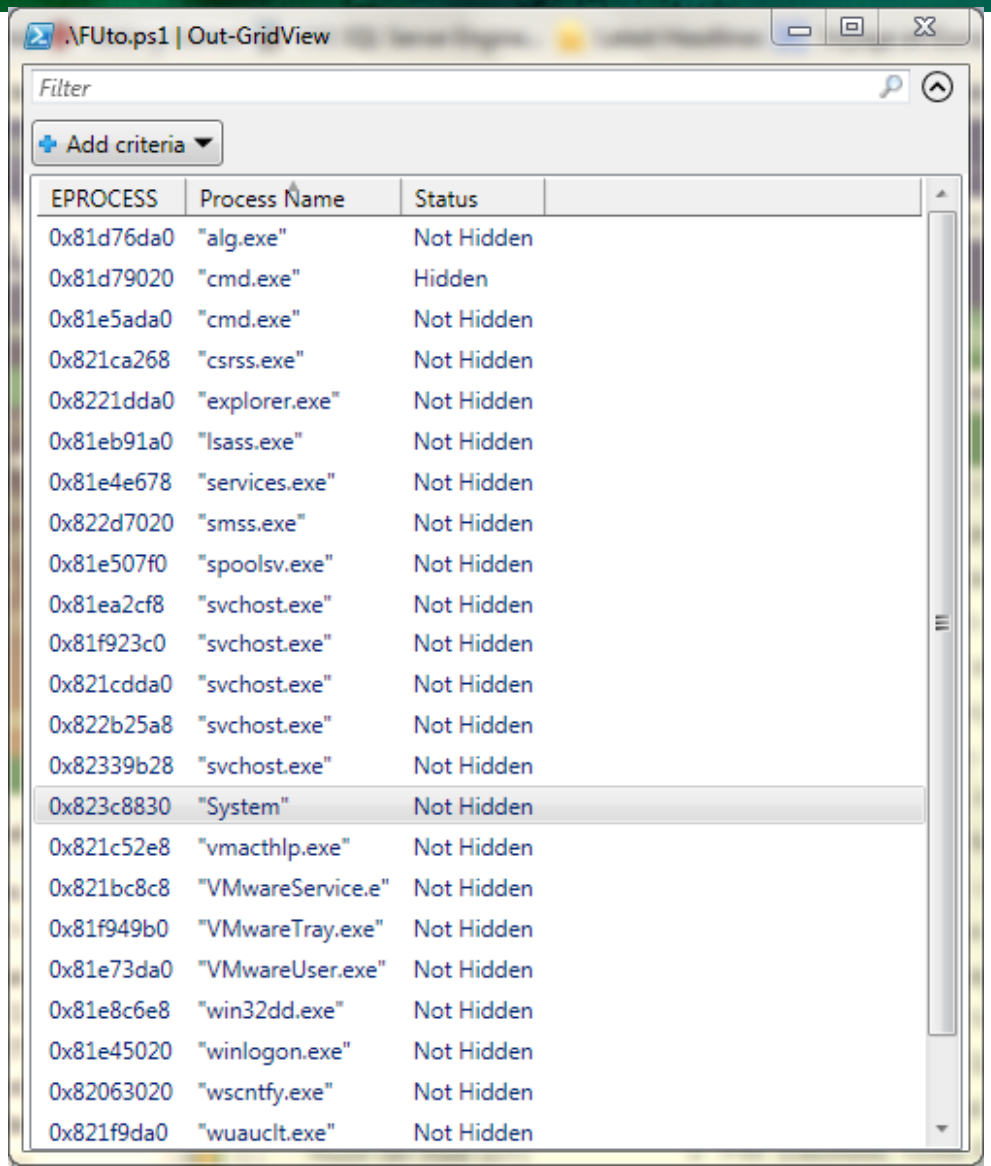
Futo.ps1



EPROCESS	Process Name	Status
0x81d76da0	"alg.exe"	Not Hidden
0x81d79020	"cmd.exe"	Hidden
0x81e5ada0	"cmd.exe"	Not Hidden
0x821ca268	"csrss.exe"	Not Hidden
0x8221dda0	"explorer.exe"	Not Hidden
0x81eb91a0	"lsass.exe"	Not Hidden
0x81e4e678	"services.exe"	Not Hidden
0x822d7020	"smss.exe"	Not Hidden
0x81e507f0	"spoolsv.exe"	Not Hidden
0x81ea2cf8	"svchost.exe"	Not Hidden
0x81f923c0	"svchost.exe"	Not Hidden
0x821cdda0	"svchost.exe"	Not Hidden
0x822b25a8	"svchost.exe"	Not Hidden
0x82339b28	"svchost.exe"	Not Hidden
0x823c8830	"System"	Not Hidden
0x821c52e8	"vmacthlp.exe"	Not Hidden
0x821bc8c8	"VMwareService.e"	Not Hidden
0x81f949b0	"VMwareTray.exe"	Not Hidden
0x81e73da0	"VMwareUser.exe"	Not Hidden
0x81e8c6e8	"win32dd.exe"	Not Hidden
0x81e45020	"winlogon.exe"	Not Hidden
0x82063020	"wscntfy.exe"	Not Hidden
0x821f9da0	"wuauclt.exe"	Not Hidden

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Future

- 64-bits version
- Improved anti-anti-forensics features
  - Less dependency with native functions
  - Improvement of memory ranges manipulation
  - Etc.
- Speed optimization
- Improvement of the WinDbg <-> PowerShell interface

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Conclusions

- **Win32dd** is a free tool for Windows physical memory snap shooting.
- **Win32dd** supports a wide range of Windows versions from Windows 2000 to Windows 7.
- **Win32dd** can produce handful snapshot like Microsoft crash dump file.
- **WinDbg** is great to analyze Microsoft crash dump files.

Ressources

- *Win32dd* (M. Suiche)
  - http://win32dd.msuiche.net
- *Microsoft Crash Dump Analysis weaknesses* (M. Suiche)
  - http://www.msuiche.net/2008/10/16/microsoft-crash-dump-analysis-weaknesses/
- *Pre-boot authentification password* (J. Brossard)
  - http://www.ivizsecurity.com/research/preboot/preboot_whitepaper.pdf
- *Rustock.C When a myth comes true* (F. Boldewin)
  - http://www.reconstructer.org/papers/Rustock.C%20-%20When%20a%20myth%20comes%20true.pdf
- *PowerDbg - Automated Debugging using WinDbg and PowerShell (R. A. Farah)*
  - http://www.codeplex.com/powerdbg
- *Win32dd – Memory Imaging*, Debugged! MZ/PE: MagaZine for/from Practicing Engineers #1 (D. Vostokov, M. Suiche, R. A. Farah)
  - (ISBN-13: 978-1906717384)
- *Pushing Limits of Windows: Physical Memory* (M. Russinovich)
  - http://blogs.technet.com/markrussinovich/archive/2008/07/21/3092070.aspx
- *MemInfo: Peer Inside Memory Manager Behavior on Windows Vista and Server 2008*
  - http://www.alex-ionescu.com/?p=51
- *ShellRunas* (M. Russinovich & J. Schwartz)
  - http://technet.microsoft.com/en-us/sysinternals/cc300361.aspx
- *Détection de processus cachés* (G.Vincent)
  - https://www.lasecuriteoffensive.fr/drup/d%C3%A9tection-de-processus-cach%C3%A9s