BLUE COAT®

Security
Empowers
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PE/COFF

AN INTRODUCTION

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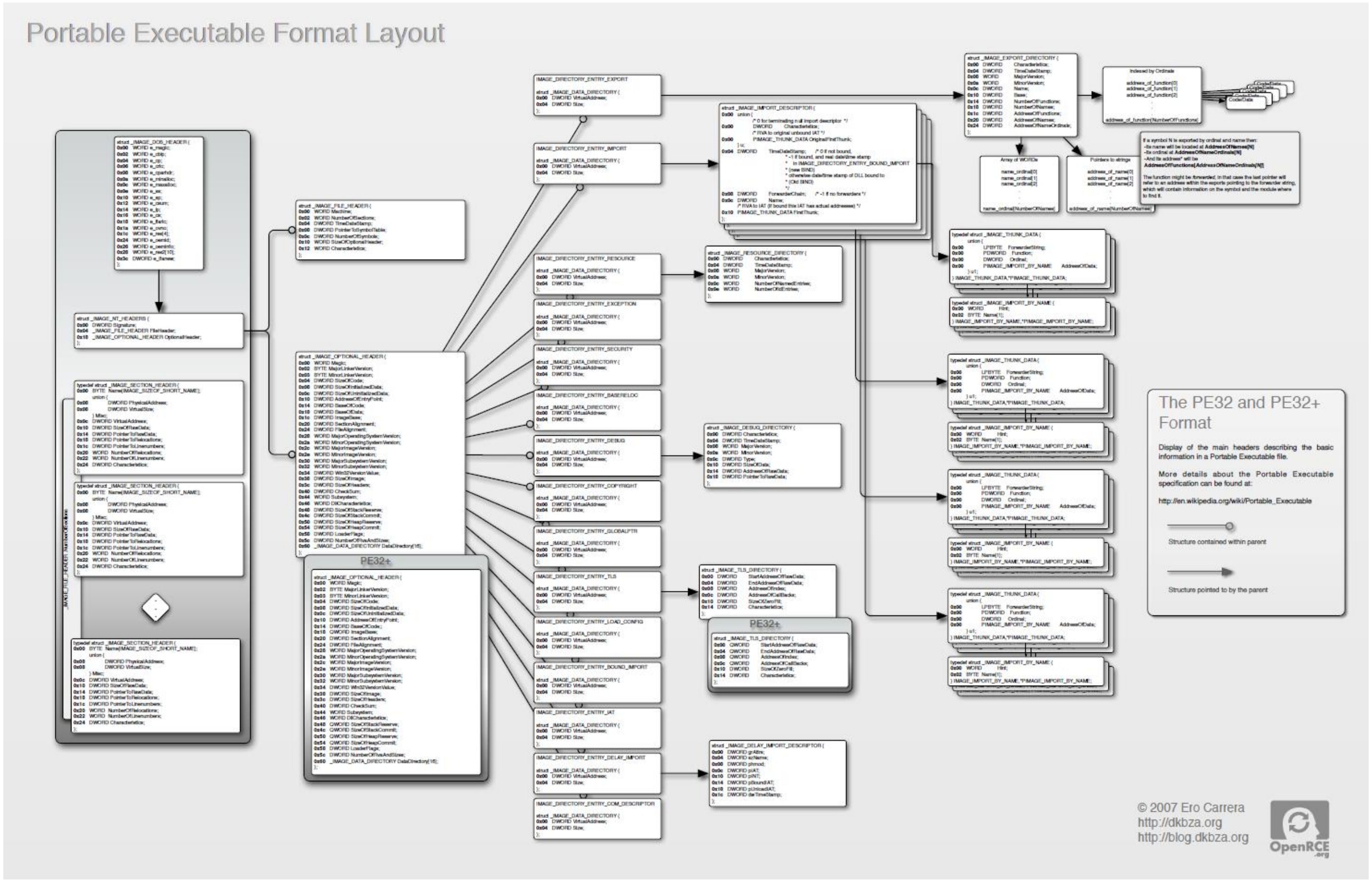
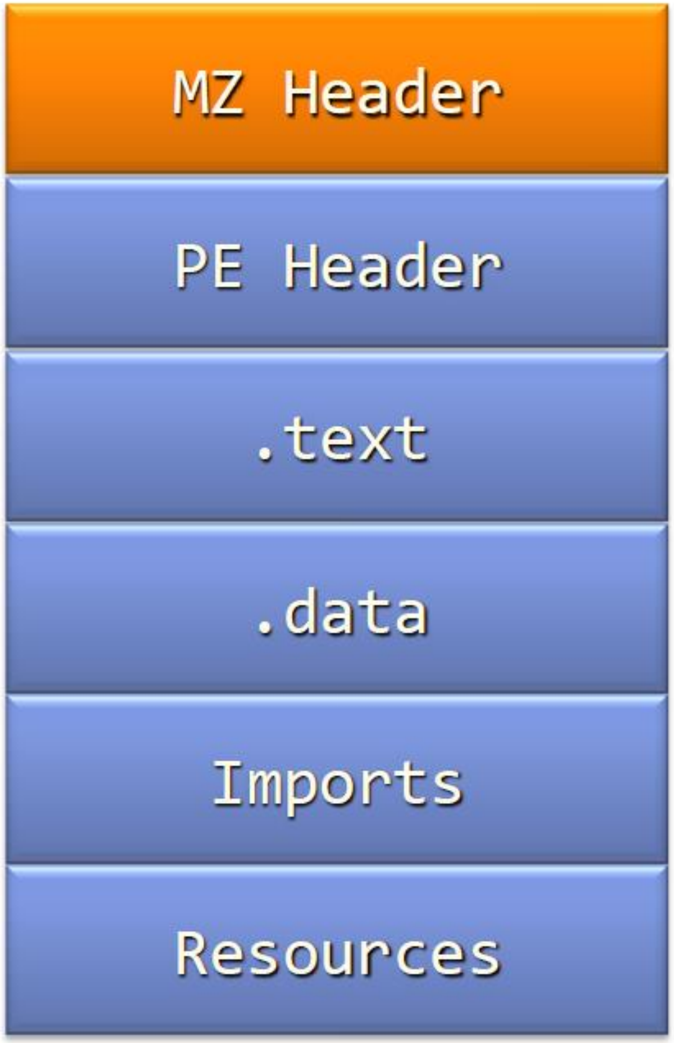
INTRODUCTION TO PE/COFF

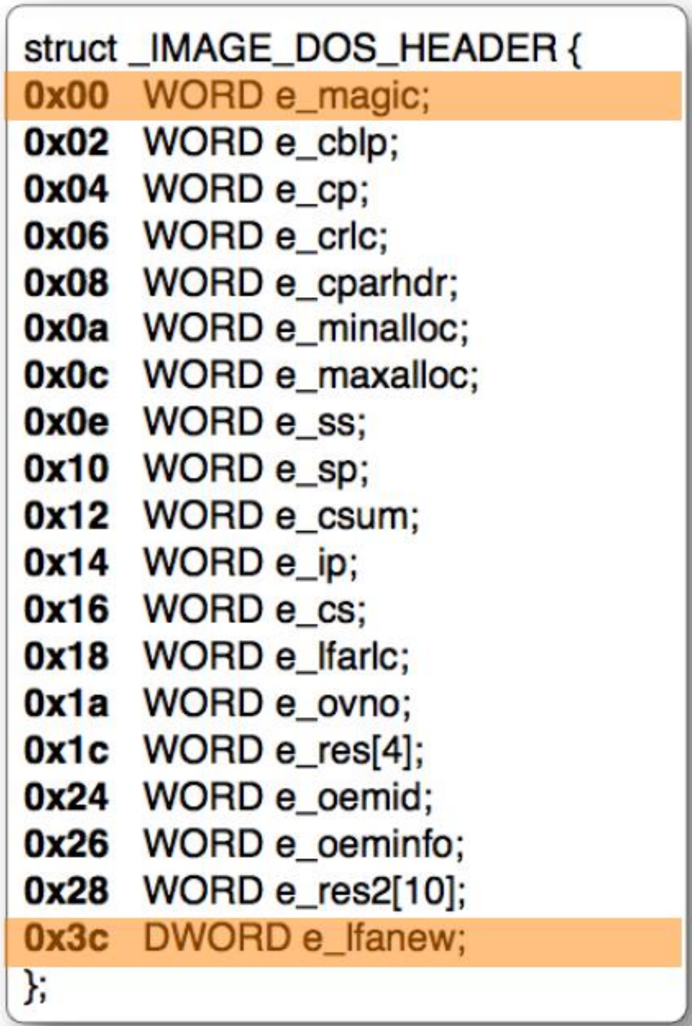
- PE stands for Portable Executable
- Microsoft introduced PE in Windows NT 3.1
- It originates from Unix COFF
- Features dynamic linking, symbol exporting/importing
- Can contain Intel, Alpha, MIPS and even .NET MSIL binary code
- 64-bit version is called PE32+

PE FORMAT LAYOUT


Portable Executable Format Layout
IMAGE_DOS_HEADER
IMAGE_NT_HEADERS
IMAGE_FILE_HEADER
IMAGE_OPTIONAL_HEADER
PE32+
IMAGE_SECTION_HEADER
IMAGE_DIRECTORY_ENTRY_EXPORT
IMAGE_DIRECTORY_ENTRY_IMPORT
IMAGE_DIRECTORY_ENTRY_RESOURCE
IMAGE_DIRECTORY_ENTRY_EXCEPTION
IMAGE_DIRECTORY_ENTRY_SECURITY
IMAGE_DIRECTORY_ENTRY_BASERELOC
IMAGE_DIRECTORY_ENTRY_DEBUG
IMAGE_DIRECTORY_ENTRY_COPYRIGHT
IMAGE_DIRECTORY_ENTRY_GLOBALPTR
IMAGE_DIRECTORY_ENTRY_TLS
IMAGE_DIRECTORY_ENTRY_LOAD_CONFIG
IMAGE_DIRECTORY_ENTRY_BOUND_IMPORT
IMAGE_DIRECTORY_ENTRY_IAT
IMAGE_DIRECTORY_ENTRY_DELAY_IMPORT
IMAGE_DIRECTORY_ENTRY_COM_DESCRIPTOR
IMAGE_EXPORT_DIRECTORY
IMAGE_IMPORT_DESCRIPTOR
IMAGE_RESOURCE_DIRECTORY
IMAGE_DEBUG_DIRECTORY
IMAGE_TLS_DIRECTORY
IMAGE_DELAY_IMPORT_DESCRIPTOR
IMAGE_THUNK_DATA
IMAGE_IMPORT_BY_NAME
The PE32 and PE32+ Format
Display of the main headers describing the basic information in a Portable Executable file.
More details about the Portable Executable specification can be found at:
http://en.wikipedia.org/wiki/Portable_Executable
Structure contained within parent
Structure pointed to by the parent
© 2007 Ero Carrera
http://dkbza.org
http://blog.dkbza.org
OpenRCE.org

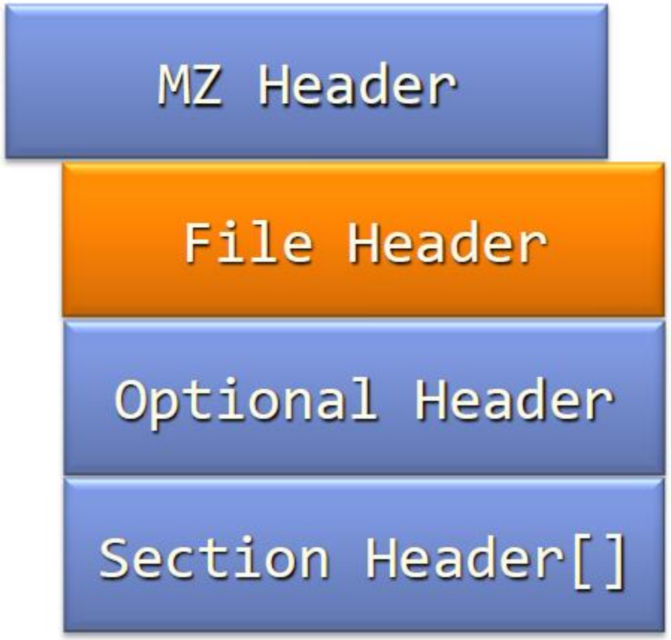
MZ HEADER

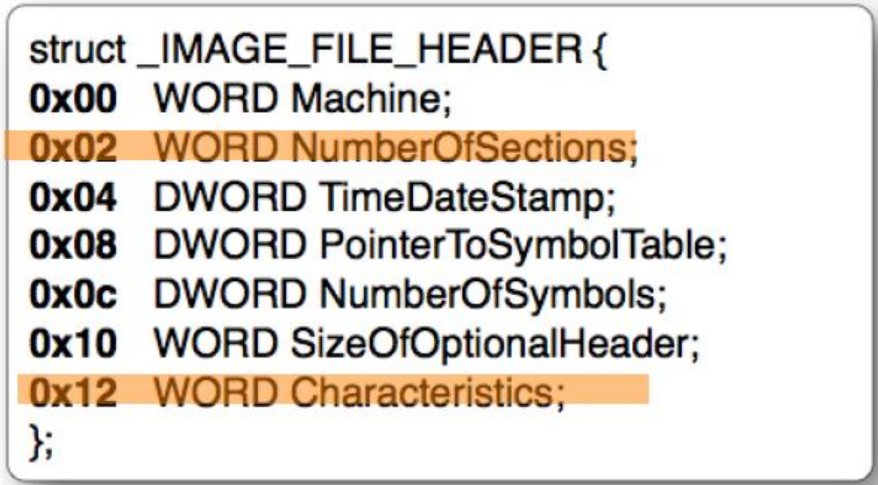




```
struct _IMAGE_DOS_HEADER {
0x00  WORD e_magic;
0x02  WORD e_cblp;
0x04  WORD e_cp;
0x06  WORD e_crlc;
0x08  WORD e_cparhdr;
0x0a  WORD e_minalloc;
0x0c  WORD e_maxalloc;
0x0e  WORD e_ss;
0x10  WORD e_sp;
0x12  WORD e_csum;
0x14  WORD e_ip;
0x16  WORD e_cs;
0x18  WORD e_lfarlc;
0x1a  WORD e_ovno;
0x1c  WORD e_res[4];
0x24  WORD e_oemid;
0x26  WORD e_oeminfo;
0x28  WORD e_res2[10];
0x3c  DWORD e_lfanew;
};
```

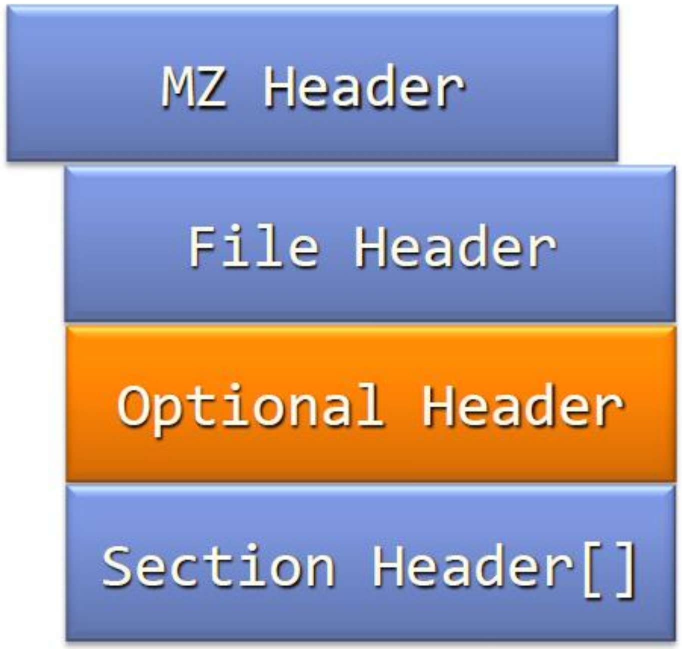
PE HEADER – FILE HEADER

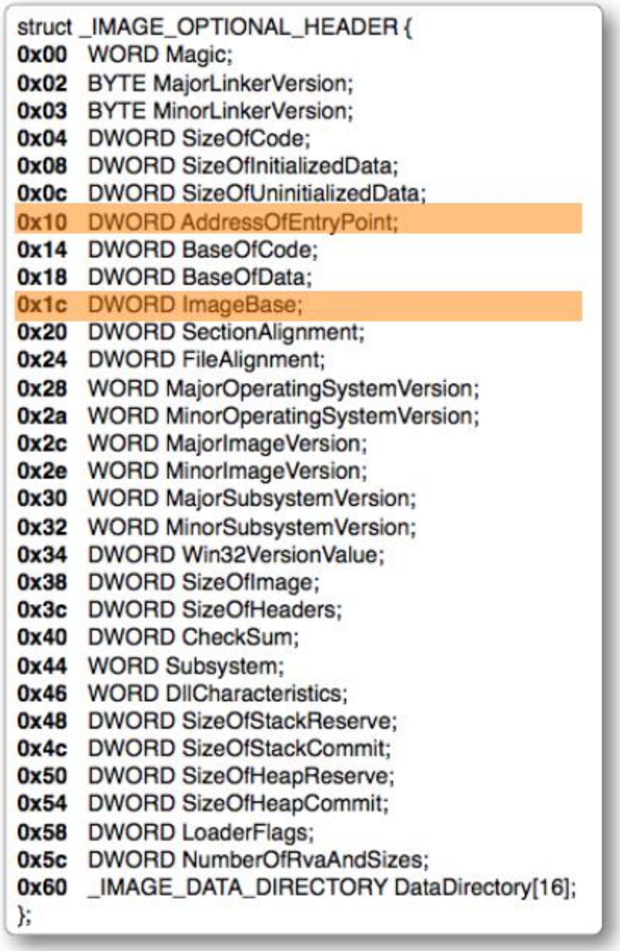




```
struct _IMAGE_FILE_HEADER {
0x00   WORD Machine;
0x02   WORD NumberOfSections;
0x04   DWORD TimeDateStamp;
0x08   DWORD PointerToSymbolTable;
0x0c   DWORD NumberOfSymbols;
0x10   WORD SizeOfOptionalHeader;
0x12   WORD Characteristics;
};
```

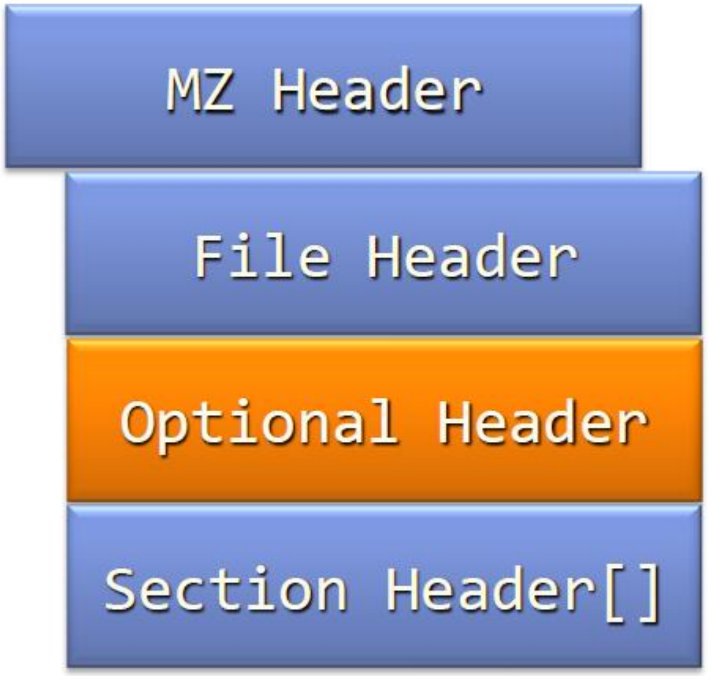
PE HEADER – OPTIONAL HEADER

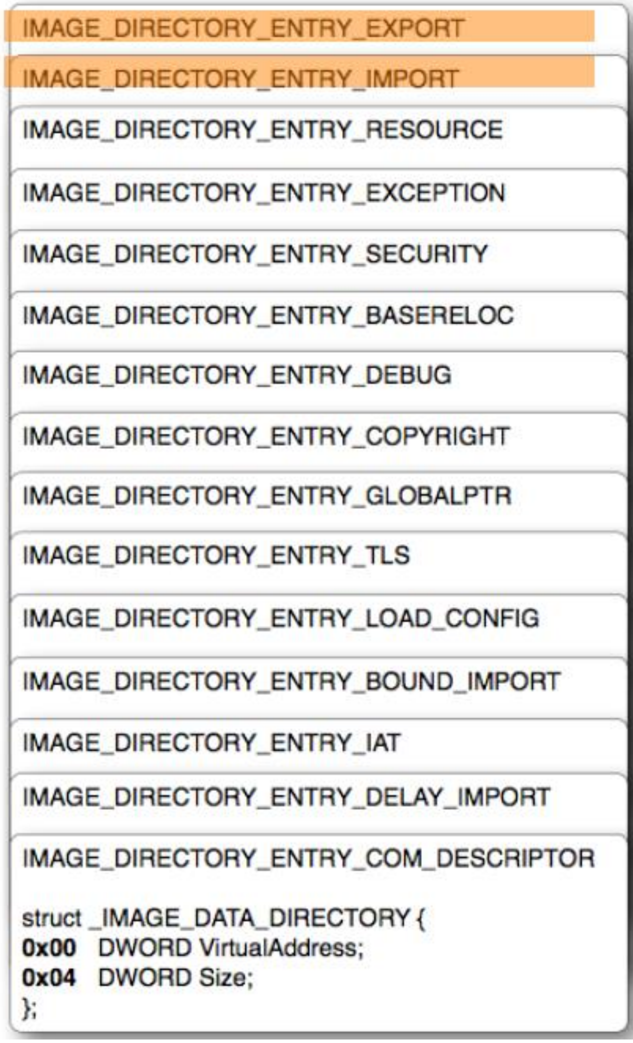




```
struct _IMAGE_OPTIONAL_HEADER {
0x00   WORD Magic;
0x02   BYTE MajorLinkerVersion;
0x03   BYTE MinorLinkerVersion;
0x04   DWORD SizeOfCode;
0x08   DWORD SizeOfInitializedData;
0x0c   DWORD SizeOfUninitializedData;
0x10   DWORD AddressOfEntryPoint;
0x14   DWORD BaseOfCode;
0x18   DWORD BaseOfData;
0x1c   DWORD ImageBase;
0x20   DWORD SectionAlignment;
0x24   DWORD FileAlignment;
0x28   WORD MajorOperatingSystemVersion;
0x2a   WORD MinorOperatingSystemVersion;
0x2c   WORD MajorImageVersion;
0x2e   WORD MinorImageVersion;
0x30   WORD MajorSubsystemVersion;
0x32   WORD MinorSubsystemVersion;
0x34   DWORD Win32VersionValue;
0x38   DWORD SizeOfImage;
0x3c   DWORD SizeOfHeaders;
0x40   DWORD CheckSum;
0x44   WORD Subsystem;
0x46   WORD DllCharacteristics;
0x48   DWORD SizeOfStackReserve;
0x4c   DWORD SizeOfStackCommit;
0x50   DWORD SizeOfHeapReserve;
0x54   DWORD SizeOfHeapCommit;
0x58   DWORD LoaderFlags;
0x5c   DWORD NumberOfRvaAndSizes;
0x60   _IMAGE_DATA_DIRECTORY DataDirectory[16];
};
```

PE HEADER – OPTIONAL HEADER – DATA DIRECTORY





IMAGE_DIRECTORY_ENTRY_EXPORT
IMAGE_DIRECTORY_ENTRY_IMPORT
IMAGE_DIRECTORY_ENTRY_RESOURCE
IMAGE_DIRECTORY_ENTRY_EXCEPTION
IMAGE_DIRECTORY_ENTRY_SECURITY
IMAGE_DIRECTORY_ENTRY_BASERELOC
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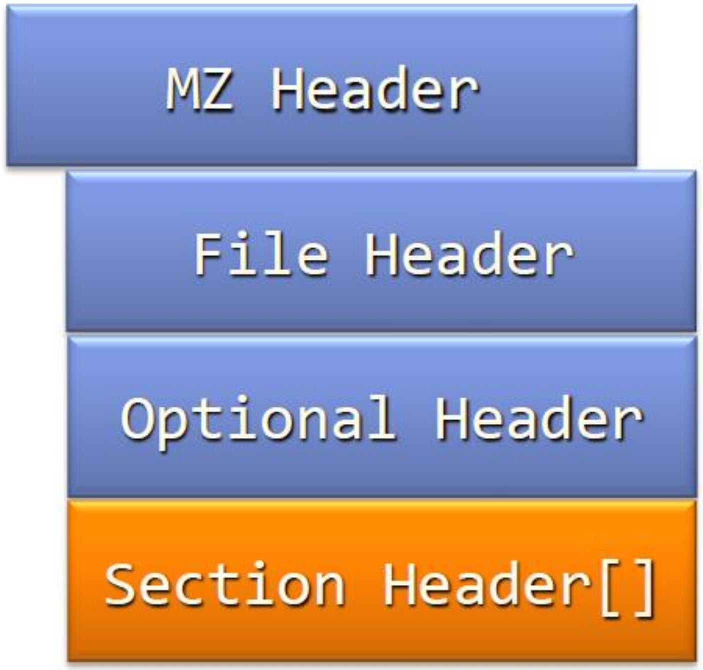
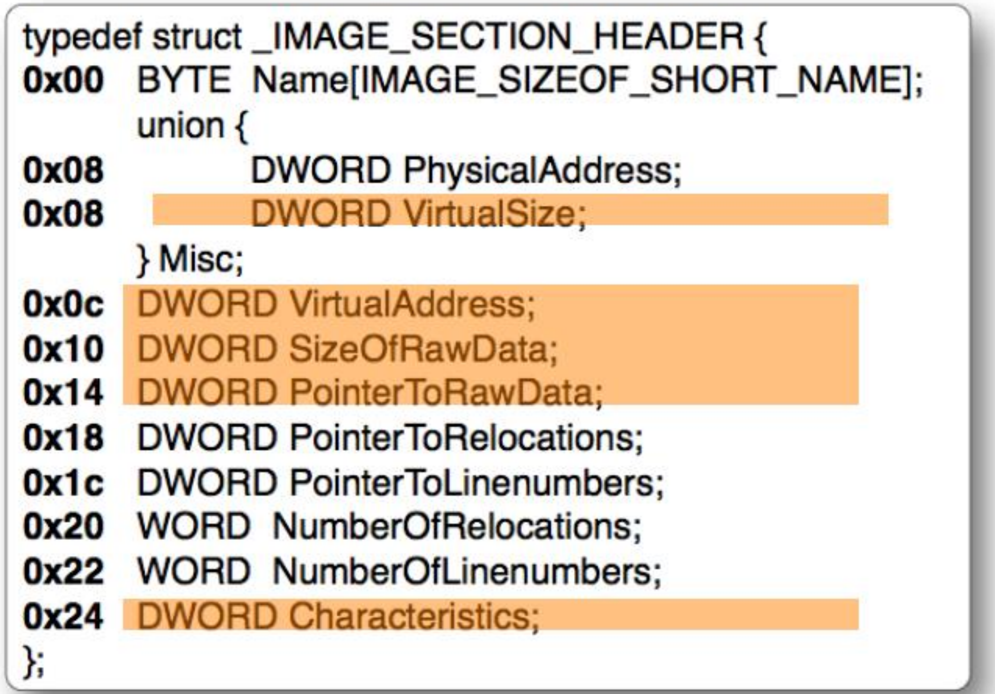
IMAGE_DIRECTORY_ENTRY_TLS
IMAGE_DIRECTORY_ENTRY_LOAD_CONFIG
IMAGE_DIRECTORY_ENTRY_BOUND_IMPORT
IMAGE_DIRECTORY_ENTRY_IAT
IMAGE_DIRECTORY_ENTRY_DELAY_IMPORT
IMAGE_DIRECTORY_ENTRY_COM_DESCRIPTOR

```
struct _IMAGE_DATA_DIRECTORY {
0x00   DWORD VirtualAddress;
0x04   DWORD Size;
};
```

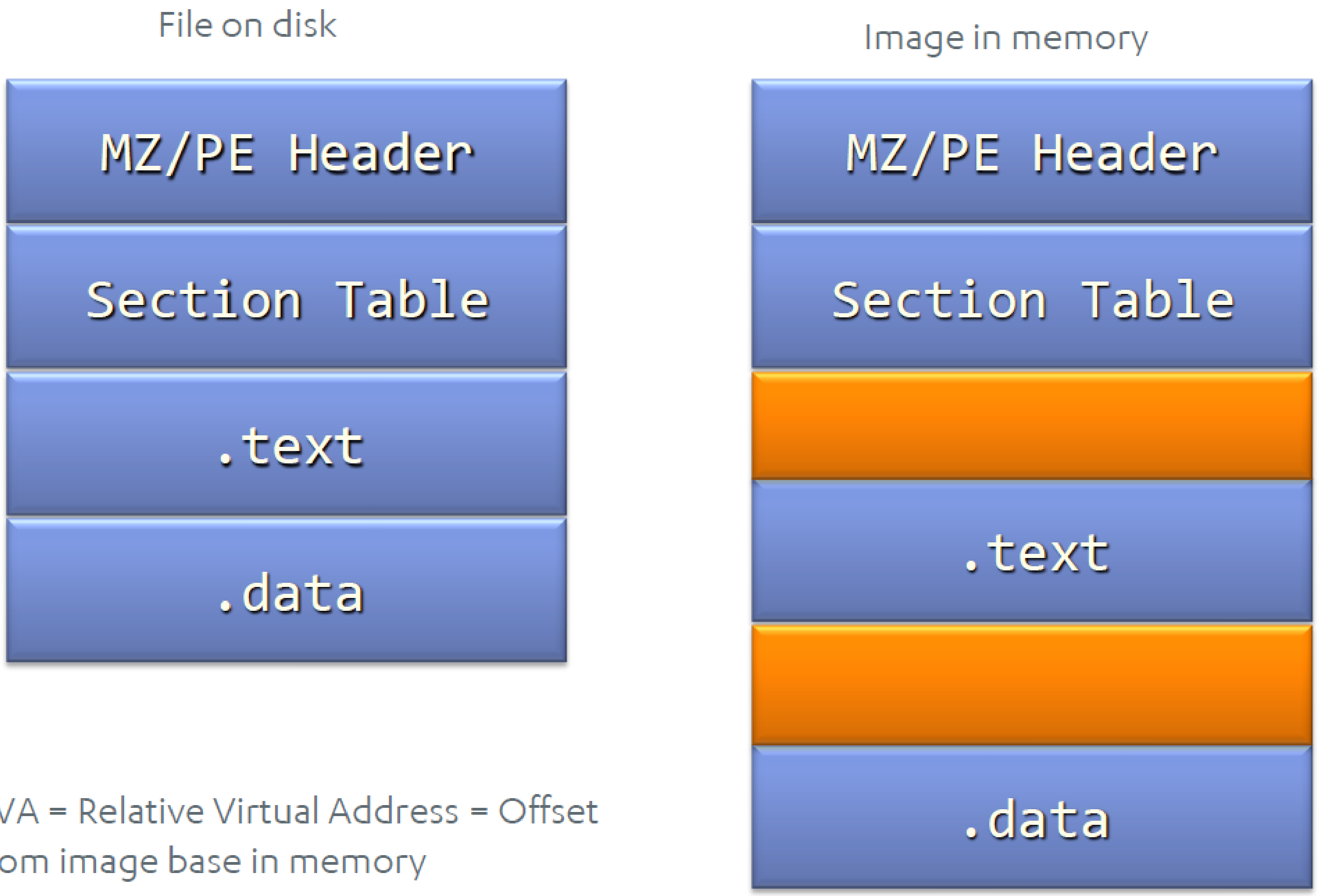
PE HEADER – SECTION HEADER





```
typedef struct _IMAGE_SECTION_HEADER {
0x00   BYTE  Name[IMAGE_SIZEOF_SHORT_NAME];
       union {
0x08        DWORD PhysicalAddress;
0x08        DWORD VirtualSize;
       } Misc;
0x0c   DWORD VirtualAddress;
0x10   DWORD SizeOfRawData;
0x14   DWORD PointerToRawData;
0x18   DWORD PointerToRelocations;
0x1c   DWORD PointerToLinenumbers;
0x20   WORD  NumberOfRelocations;
0x22   WORD  NumberOfLinenumbers;
0x24   DWORD Characteristics;
};
```

PE LOADING



RVA = Relative Virtual Address = Offset from image base in memory

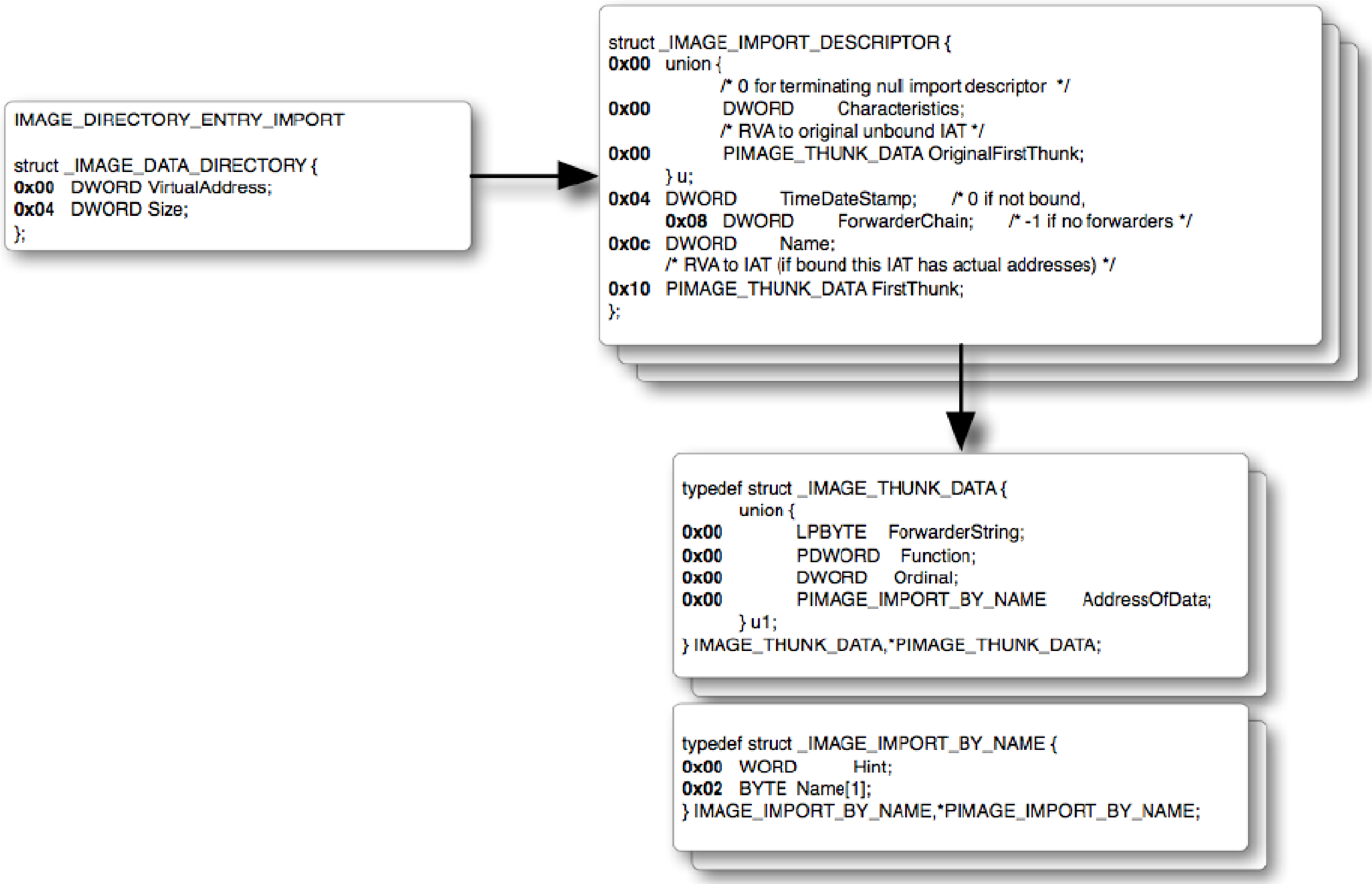
IMPORTING SYMBOLS

- Symbols (functions/data) can be imported from external DLLs
- The loader will load external DLLs automatically
- All the dependencies are loaded as well
- DLLs will be loaded only once
- External addresses are written to the Import Address Table (IAT)

IMPORTING SYMBOLS - CONTINUED

- **Every PE has one IMAGE_IMPORT_DESCRIPTOR**
- **The descriptor points to two parallel lists of symbols to import**
  - Import Address Table (IAT)
  - Import Name Table (INT)
- **The primary list (IAT) is overwritten by the loader, the second one is not**
- **Executables can be pre-bound to DLLs to speed up loading**
- **Symbols can be imported by ASCII name or ordinal (usually by Name)**

IMPORT DESCRIPTORS



```
IMAGE_DIRECTORY_ENTRY_IMPORT

struct _IMAGE_DATA_DIRECTORY {
0x00   DWORD VirtualAddress;
0x04   DWORD Size;
};
```

```
struct _IMAGE_IMPORT_DESCRIPTOR {
0x00  union {
          /* 0 for terminating null import descriptor  */
0x00      DWORD       Characteristics;
          /* RVA to original unbound IAT */
0x00      PIMAGE_THUNK_DATA OriginalFirstThunk;
      } u;
0x04  DWORD       TimeDateStamp;     /* 0 if not bound,
      0x08  DWORD       ForwarderChain;     /* -1 if no forwarders */
0x0c  DWORD       Name;
      /* RVA to IAT (if bound this IAT has actual addresses) */
0x10  PIMAGE_THUNK_DATA FirstThunk;
};
```

```
typedef struct _IMAGE_THUNK_DATA {
      union {
0x00          LPBYTE    ForwarderString;
0x00          PDWORD    Function;
0x00          DWORD     Ordinal;
0x00          PIMAGE_IMPORT_BY_NAME      AddressOfData;
      } u1;
} IMAGE_THUNK_DATA,*PIMAGE_THUNK_DATA;
```

```
typedef struct _IMAGE_IMPORT_BY_NAME {
0x00   WORD       Hint;
0x02   BYTE  Name[1];
} IMAGE_IMPORT_BY_NAME,*PIMAGE_IMPORT_BY_NAME;
```

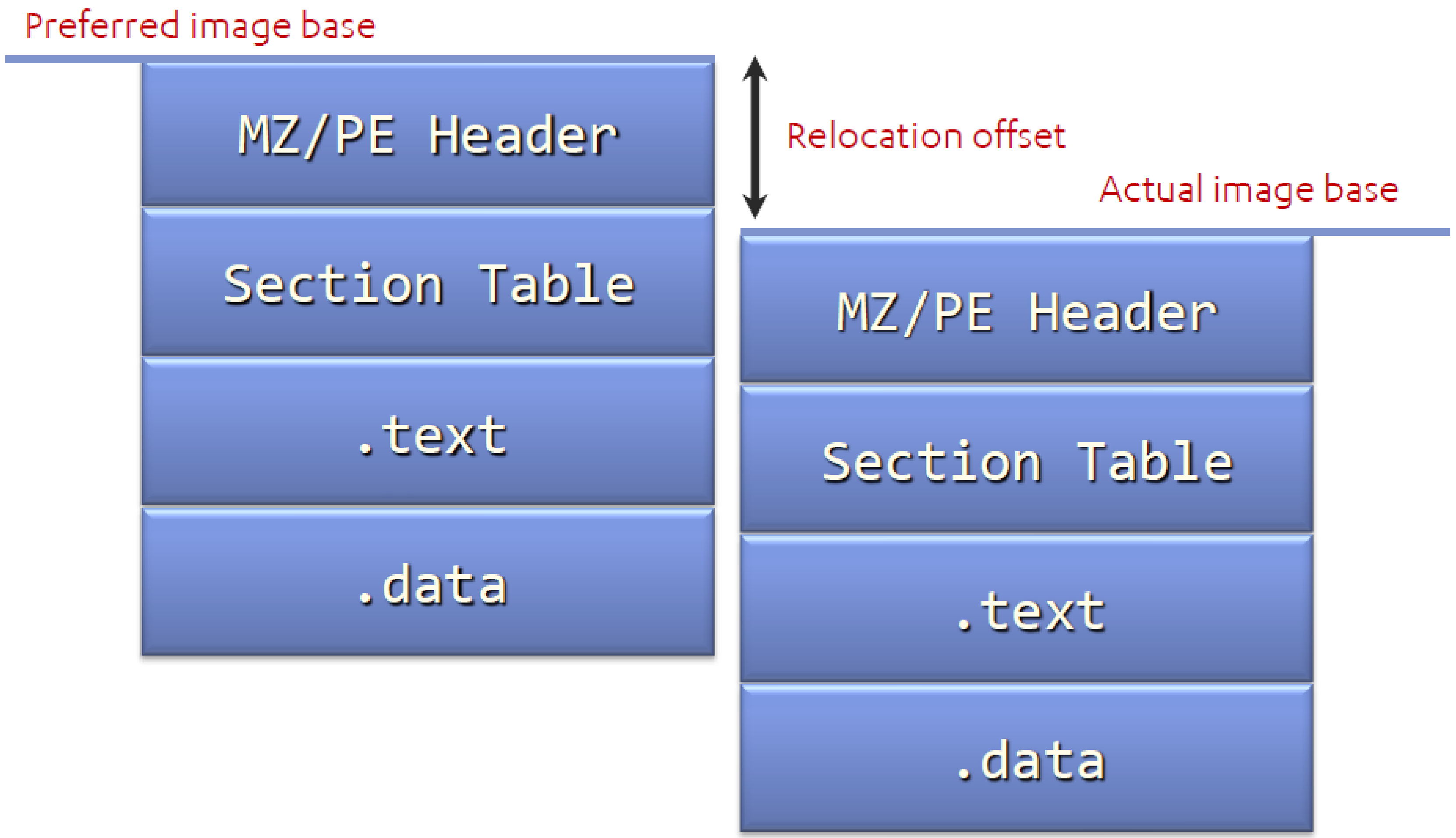
EXPORTS

- Symbols can be exported with ordinals, names or both
- Ordinals are simple index numbers of symbols
- Name is a full ASCII name of the exported symbol
- Exports can be forwarded to another DLL
- Forwarded symbol’s address points to a name in the exports section

RESOURCE

- Resources in PE are similar to an archive
- Resource files can be organized into directory trees
- The data structure is quite complex but there are tools to handle it
- Most common resources:
  - Icons
  - Version information
  - GUI resources

BASE RELOCATION



REFERENCES

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- PE File Format Graphs
  - http://blog.dkbza.org/2012/08/pe-file-format-graphs.html
- Understanding RVAs and Import Tables
  - http://www.sunshine2k.de/reversing/tuts/tut_rvait.htm
- Paolo Palumbo
  - https://www.linkedin.com/in/paolopalumbo
  - Thanks for the beautiful slides