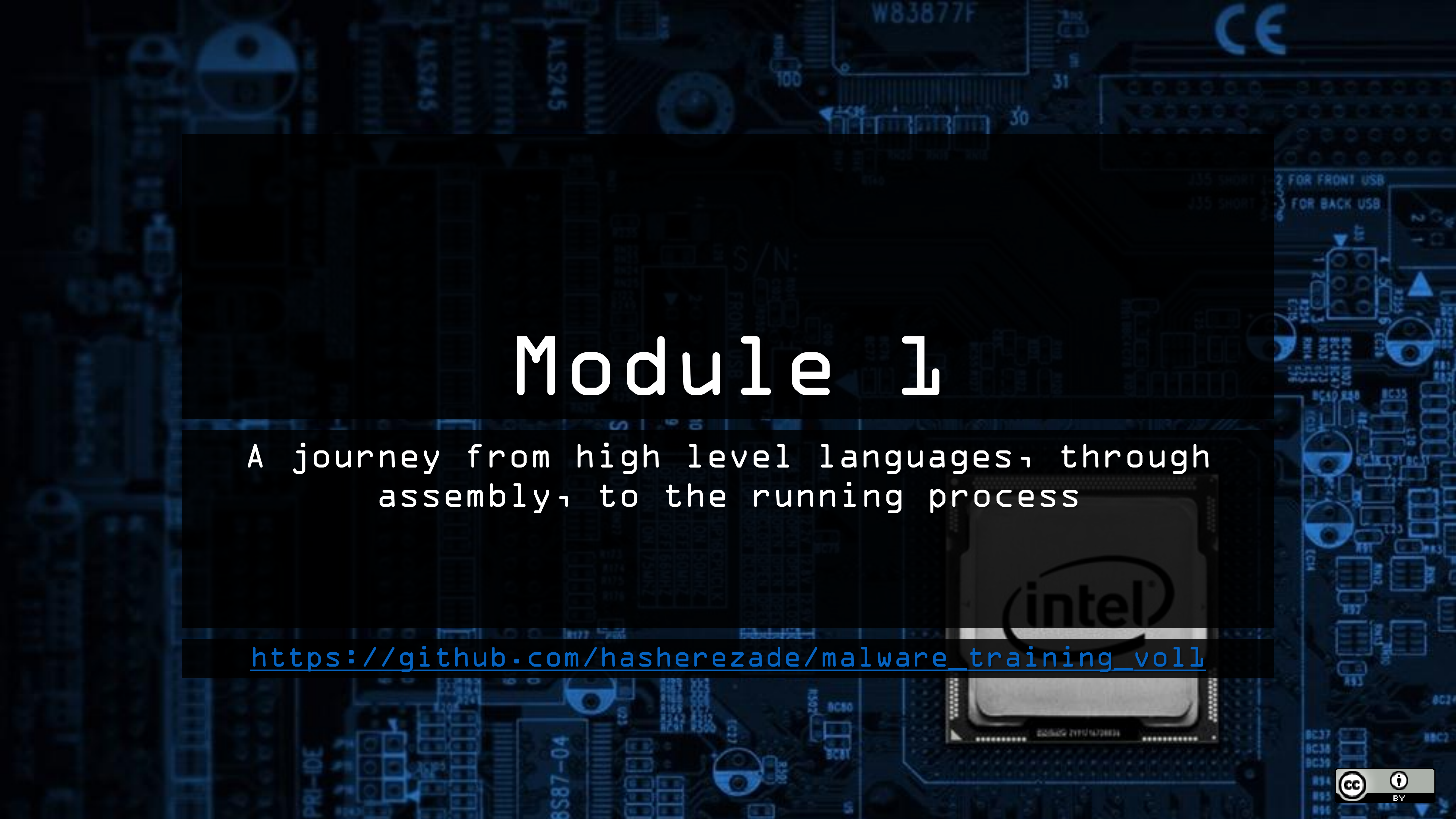


Module 1

A journey from high level languages, through assembly, to the running process

https://github.com/hasherezade/malware_training_vol1

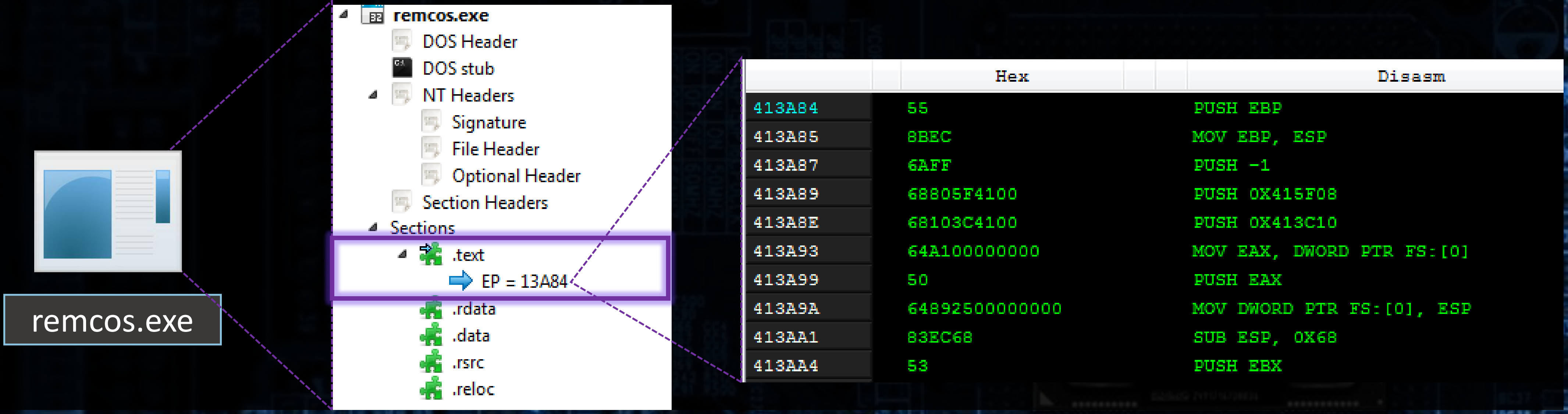
Basics of PE (Portable Executable)

Basics of a PE file

- PE (Portable Executable) is a native executable format on Windows
- PE files:
  - user mode: EXE, DLL
  - kernel mode: driver (.sys), kernel image (ntoskrnl.exe)
  - UEFI (run in SMM – System Managemant Mode)
  - Also OBJ files have structures similar to PE

Basics of a PE file

- PE (Portable Executable) contains information:
  - What to execute: the compiled code
  - How to execute: headers with data necessary for loading it



remcos.exe

- remcos.exe
  - DOS Header
  - DOS stub
  - NT Headers
    - Signature
    - File Header
    - Optional Header
  - Section Headers
  - Sections
    - .text
      - EP = 13A84
    - .rdata
    - .data
    - .rsrc
    - .reloc

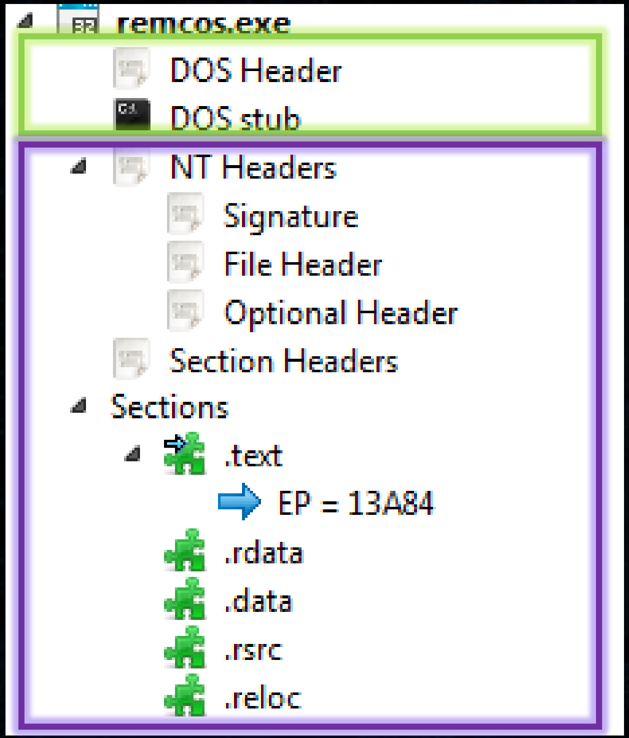
```
          Hex                 Disasm
413A84    55                  PUSH EBP
413A85    8BEC                MOV EBP, ESP
413A87    6AFF                PUSH -1
413A89    68805F4100          PUSH 0X415F08
413A8E    68103C4100          PUSH 0X413C10
413A93    64A100000000        MOV EAX, DWORD PTR FS:[0]
413A99    50                  PUSH EAX
413A9A    64892500000000      MOV DWORD PTR FS:[0], ESP
413AA1    83EC68              SUB ESP, 0X68
413AA4    53                  PUSH EBX
```

Basics of a PE file

- PE format is based on a Unix format COFF – that was used in VAX/VMS
- It was introduced as a part of specification Win32
- Throughout many years, the core of the format didn't change, only some new fields of some structures have been added
- Since introduction of 64 bit environment, PE needed to be adjusted to it: 64 bit PE was introduced
- Also, new variants have been introduced, like .NET PE – containing additional structures with intermediate code and metadata

Basics of a PE file

- PE file structure: the DOS part (legacy) and the Windows Part

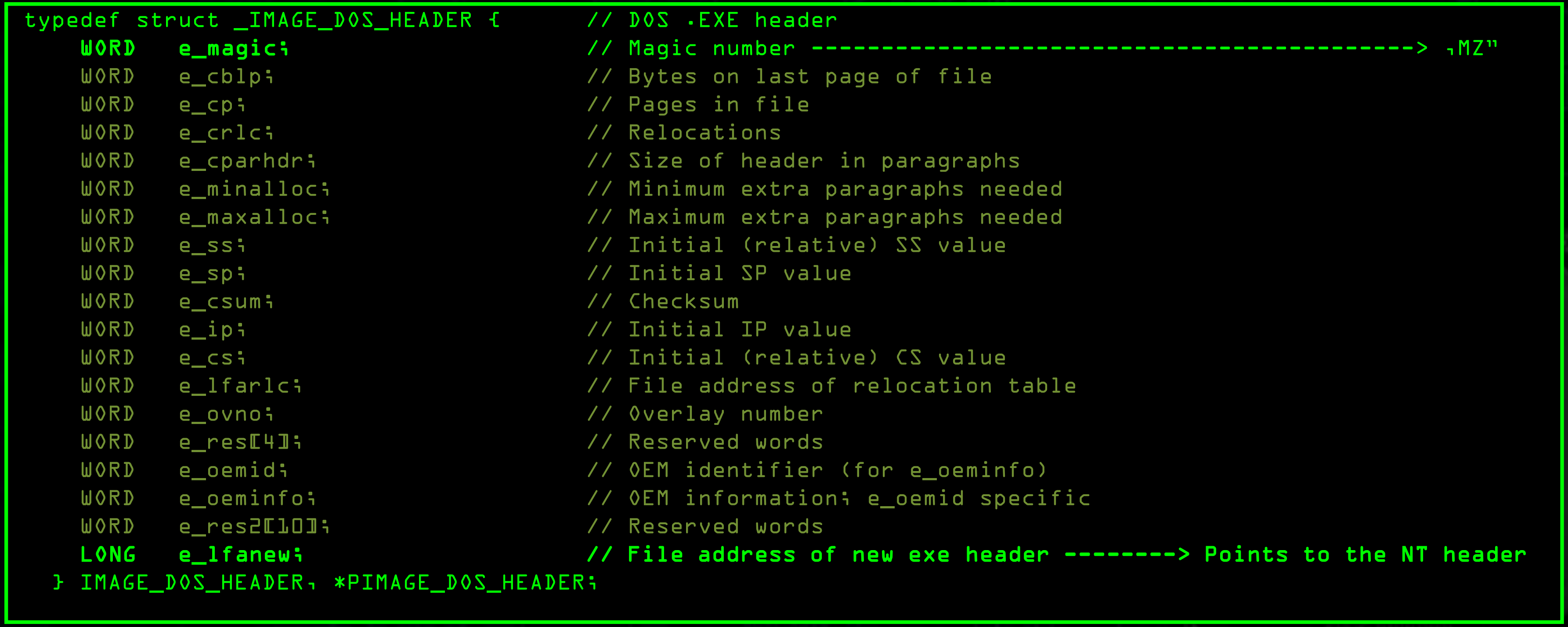


- remcos.exe
  - DOS Header
  - DOS stub
  - NT Headers
    - Signature
    - File Header
    - Optional Header
  - Section Headers
  - Sections
    - .text
      - EP = 13A84
    - .rdata
    - .data
    - .rsrc
    - .reloc

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/pe_hdr.h

Basics of a PE file

- DOS Header: only e_magic, and e_lfnew must be filled:

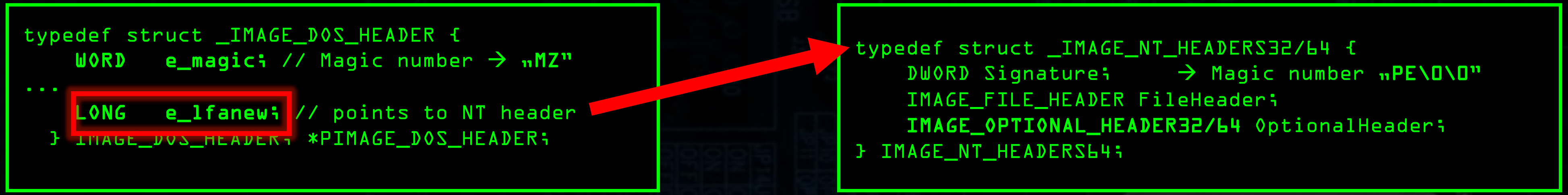


```
typedef struct _IMAGE_DOS_HEADER {      // DOS .EXE header
    WORD   e_magic;                     // Magic number ---------------------------------------------> ‚MZ”
    WORD   e_cblp;                      // Bytes on last page of file
    WORD   e_cp;                        // Pages in file
    WORD   e_crlc;                      // Relocations
    WORD   e_cparhdr;                   // Size of header in paragraphs
    WORD   e_minalloc;                  // Minimum extra paragraphs needed
    WORD   e_maxalloc;                  // Maximum extra paragraphs needed
    WORD   e_ss;                        // Initial (relative) SS value
    WORD   e_sp;                        // Initial SP value
    WORD   e_csum;                      // Checksum
    WORD   e_ip;                        // Initial IP value
    WORD   e_cs;                        // Initial (relative) CS value
    WORD   e_lfarlc;                    // File address of relocation table
    WORD   e_ovno;                      // Overlay number
    WORD   e_res[4];                    // Reserved words
    WORD   e_oemid;                     // OEM identifier (for e_oeminfo)
    WORD   e_oeminfo;                   // OEM information; e_oemid specific
    WORD   e_res2[10];                  // Reserved words
    LONG   e_lfanew;                    // File address of new exe header --------> Points to the NT header
  } IMAGE_DOS_HEADER, *PIMAGE_DOS_HEADER;
```

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/pe_hdr.h

Basics of a PE file

- DOS Header: fields to remember



```
typedef struct _IMAGE_DOS_HEADER {
    WORD   e_magic; // Magic number → „MZ"
...
    LONG   e_lfanew; // points to NT header
  } IMAGE_DOS_HEADER, *PIMAGE_DOS_HEADER;
```

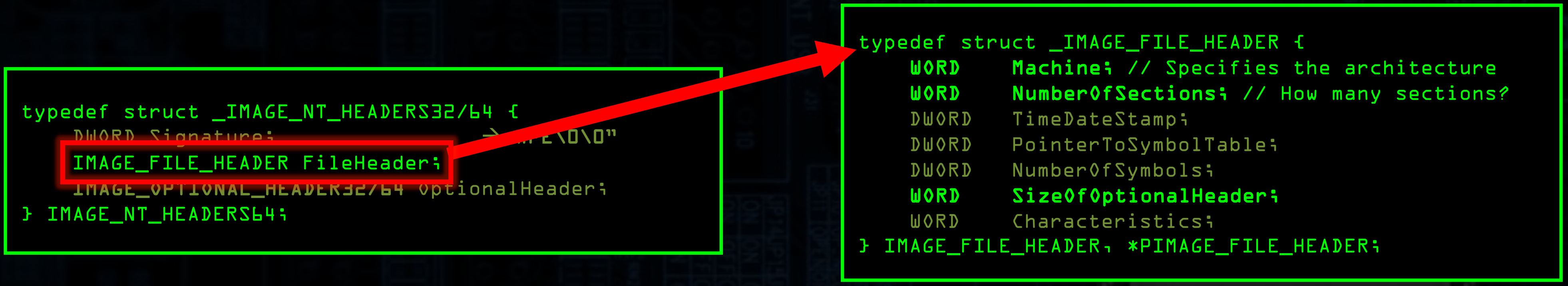
```
typedef struct _IMAGE_NT_HEADERS32/64 {
    DWORD Signature;      → Magic number „PE\0\0"
    IMAGE_FILE_HEADER FileHeader;
    IMAGE_OPTIONAL_HEADER32/64 OptionalHeader;
} IMAGE_NT_HEADERS64;
```

Let's have a look in PE-bear...

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/pe_hdr.h

Basics of a PE file

- FileHeader: fields to remember



```
typedef struct _IMAGE_NT_HEADERS32/64 {
    DWORD Signature;                → "PE\0\0"
    IMAGE_FILE_HEADER FileHeader;
    IMAGE_OPTIONAL_HEADER32/64 OptionalHeader;
} IMAGE_NT_HEADERS64;
```

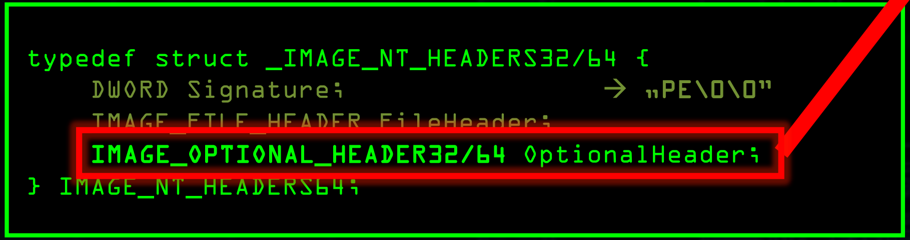
```
typedef struct _IMAGE_FILE_HEADER {
    WORD    Machine; // Specifies the architecture
    WORD    NumberOfSections; // How many sections?
    DWORD   TimeDateStamp;
    DWORD   PointerToSymbolTable;
    DWORD   NumberOfSymbols;
    WORD    SizeOfOptionalHeader;
    WORD    Characteristics;
} IMAGE_FILE_HEADER, *PIMAGE_FILE_HEADER;
```

Let's have a look in PE-bear...

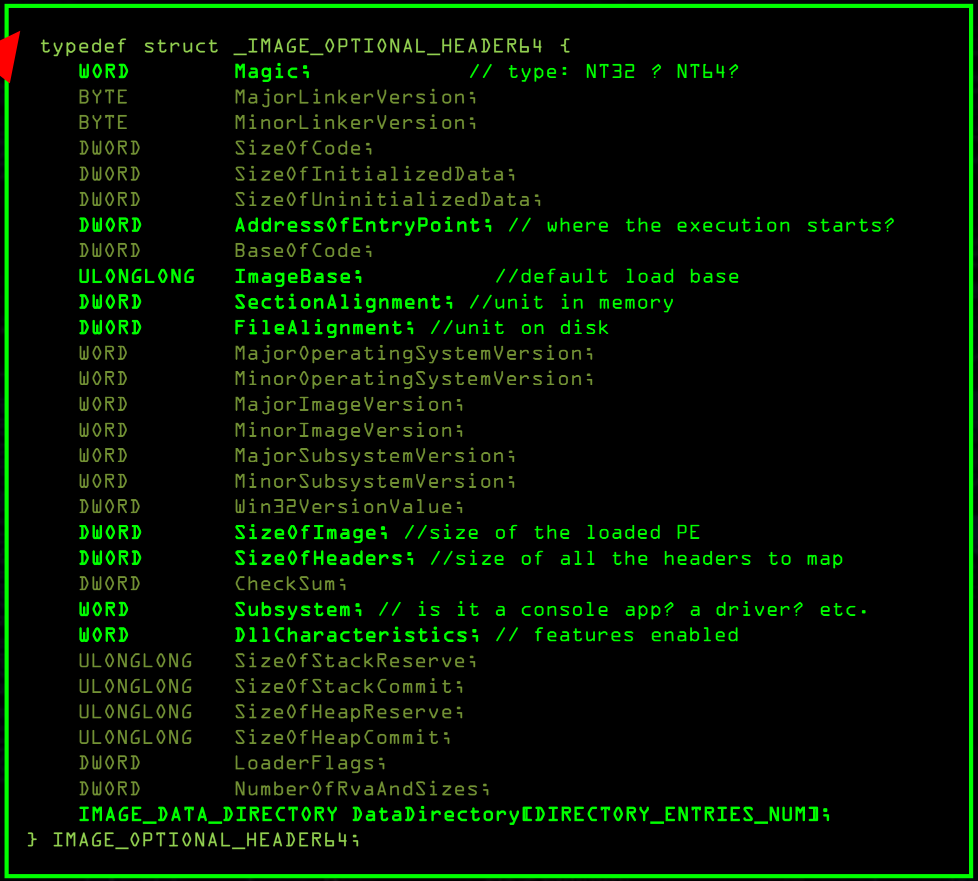
https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/pe_hdr.h

Basics of a PE file

- OptionalHeader: fields to remember



```
typedef struct _IMAGE_NT_HEADERS32/64 {
    DWORD Signature;                     → „PE\0\0"
    IMAGE_FILE_HEADER FileHeader;
    IMAGE_OPTIONAL_HEADER32/64 OptionalHeader;
} IMAGE_NT_HEADERS64;
```



```
typedef struct _IMAGE_OPTIONAL_HEADER64 {
    WORD        Magic;        // type: NT32 ? NT64?
    BYTE        MajorLinkerVersion;
    BYTE        MinorLinkerVersion;
    DWORD       SizeOfCode;
    DWORD       SizeOfInitializedData;
    DWORD       SizeOfUninitializedData;
    DWORD       AddressOfEntryPoint; // where the execution starts?
    DWORD       BaseOfCode;
    ULONGLONG   ImageBase;           //default load base
    DWORD       SectionAlignment; //unit in memory
    DWORD       FileAlignment; //unit on disk
    WORD        MajorOperatingSystemVersion;
    WORD        MinorOperatingSystemVersion;
    WORD        MajorImageVersion;
    WORD        MinorImageVersion;
    WORD        MajorSubsystemVersion;
    WORD        MinorSubsystemVersion;
    DWORD       Win32VersionValue;
    DWORD       SizeOfImage; //size of the loaded PE
    DWORD       SizeOfHeaders; //size of all the headers to map
    DWORD       CheckSum;
    WORD        Subsystem; // is it a console app? a driver? etc.
    WORD        DllCharacteristics; // features enabled
    ULONGLONG   SizeOfStackReserve;
    ULONGLONG   SizeOfStackCommit;
    ULONGLONG   SizeOfHeapReserve;
    ULONGLONG   SizeOfHeapCommit;
    DWORD       LoaderFlags;
    DWORD       NumberOfRvaAndSizes;
    IMAGE_DATA_DIRECTORY DataDirectory[DIRECTORY_ENTRIES_NUM];
} IMAGE_OPTIONAL_HEADER64;
```

Let's have a look in PE-bear...

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/pe_hdr.h

Basics of a PE file: sections

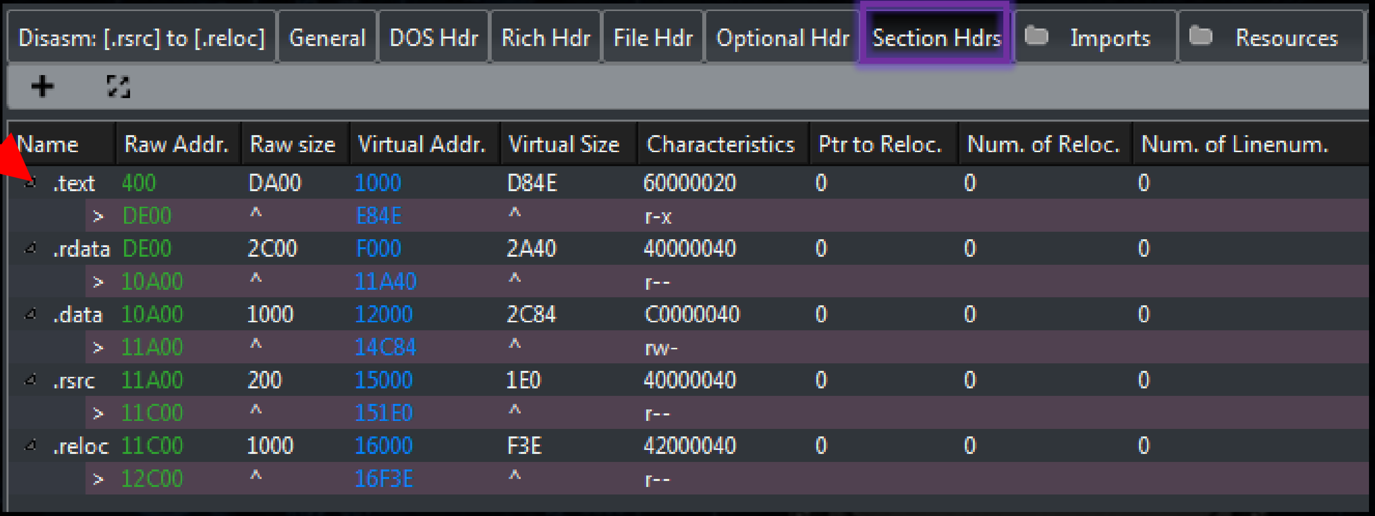
- PE is divided into sections with different permissions
- Sections introduce a logical layout of the binary, that compilers/linkers can follow
- Dividing PE on section improves security: the code is isolated from the data
- HOWEVER:
    - if DEP (Data Execution Prevention) is disabled, a page without execution permission can still be executed

Basics of a PE file: sections

- PE sections are defined by sections header

```
#define IMAGE_FIRST_SECTION( ntheader ) ((PIMAGE_SECTION_HEADER)   \
    ((ULONG_PTR)(ntheader) +                                        \
     FIELD_OFFSET( IMAGE_NT_HEADERS, OptionalHeader ) +             \
     ((ntheader))->FileHeader.SizeOfOptionalHeader   \
    ))
```

A macro in `winnt.h` pointing the first section

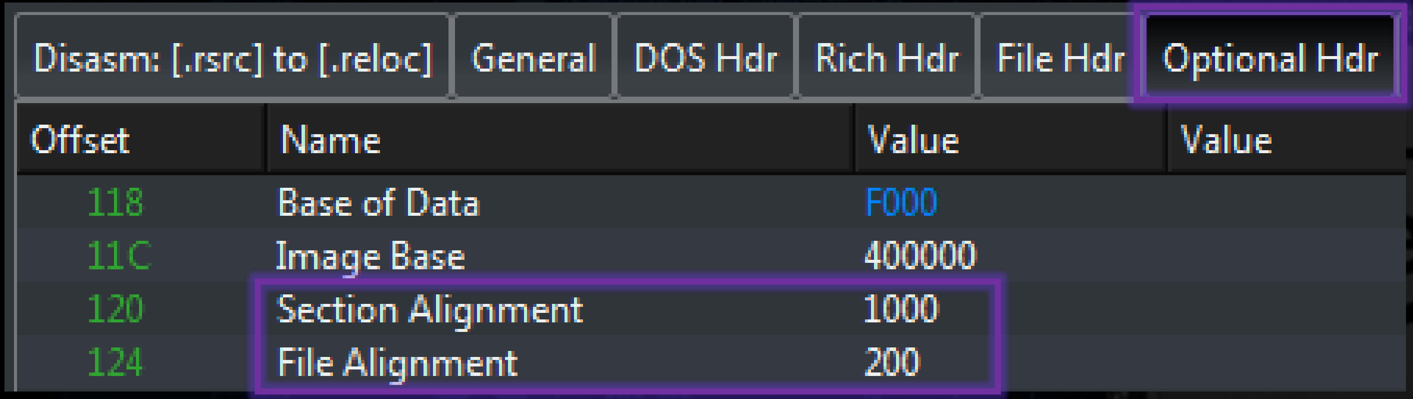


Name	Raw Addr.	Raw size	Virtual Addr.	Virtual Size	Characteristics	Ptr to Reloc.	Num. of Reloc.	Num. of Linenum.
.text	400	DA00	1000	D84E	60000020	0	0	0
>	DE00	^	E84E	^	r-x			
.rdata	DE00	2C00	F000	2A40	40000040	0	0	0
>	10A00	^	11A40	^	r--			
.data	10A00	1000	12000	2C84	C0000040	0	0	0
>	11A00	^	14C84	^	rw-			
.rsrc	11A00	200	15000	1E0	40000040	0	0	0
>	11C00	^	151E0	^	r--			
.reloc	11C00	1000	16000	F3E	42000040	0	0	0
>	12C00	^	16F3E	^	r--			

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/remap.h

Basics of a PE file: sections

- on the disk PE is stored in a raw format (the unit is defined by File Alignment)
- In memory PE is mapped to its virtual format (the unit is defined by Section Alignment) – usually of the granularity of one page (0x1000)

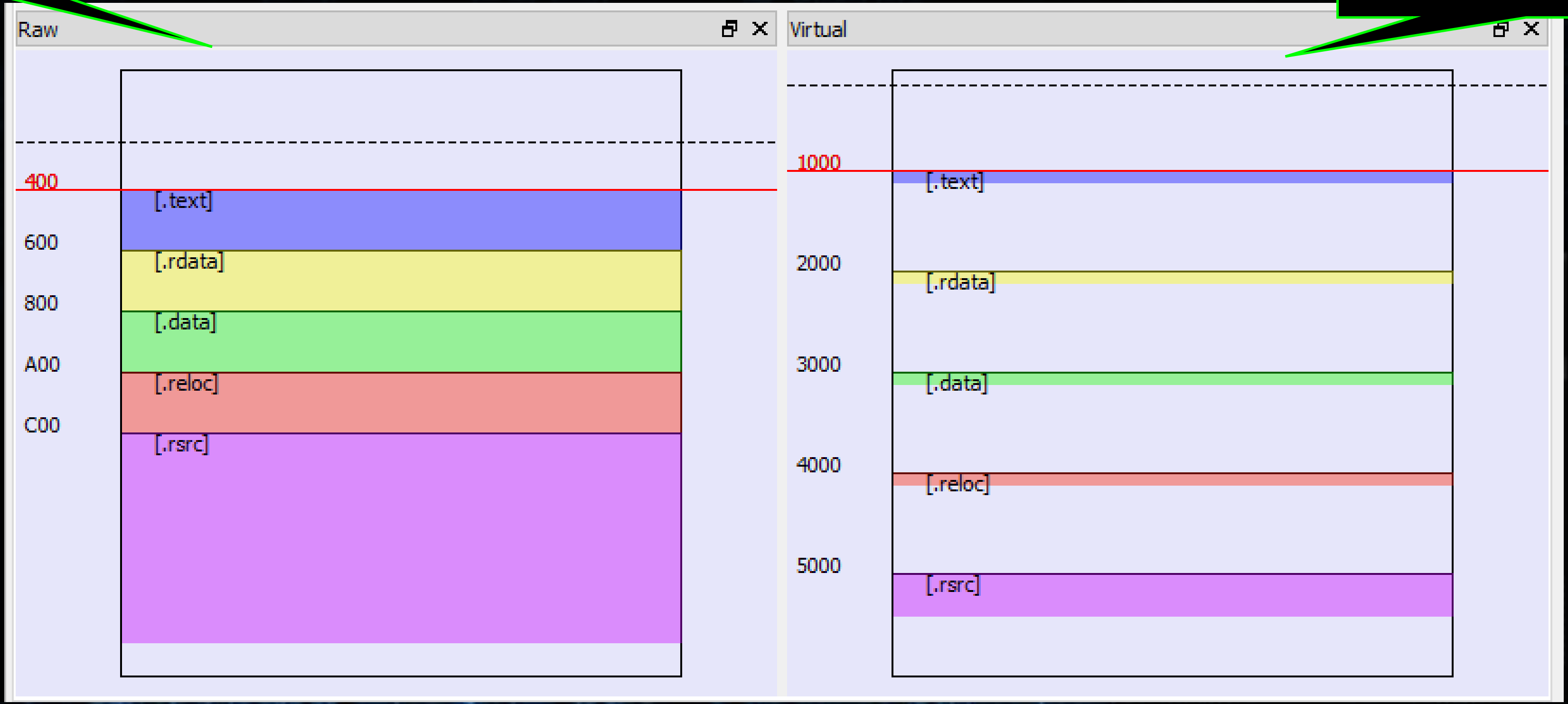


Offset	Name	Value	Value
118	Base of Data	F000	
11C	Image Base	400000	
120	Section Alignment	1000	
124	File Alignment	200	

Basics of a PE file: sections

Raw
(file on the disk)

Virtual
(mapped in the process memory)



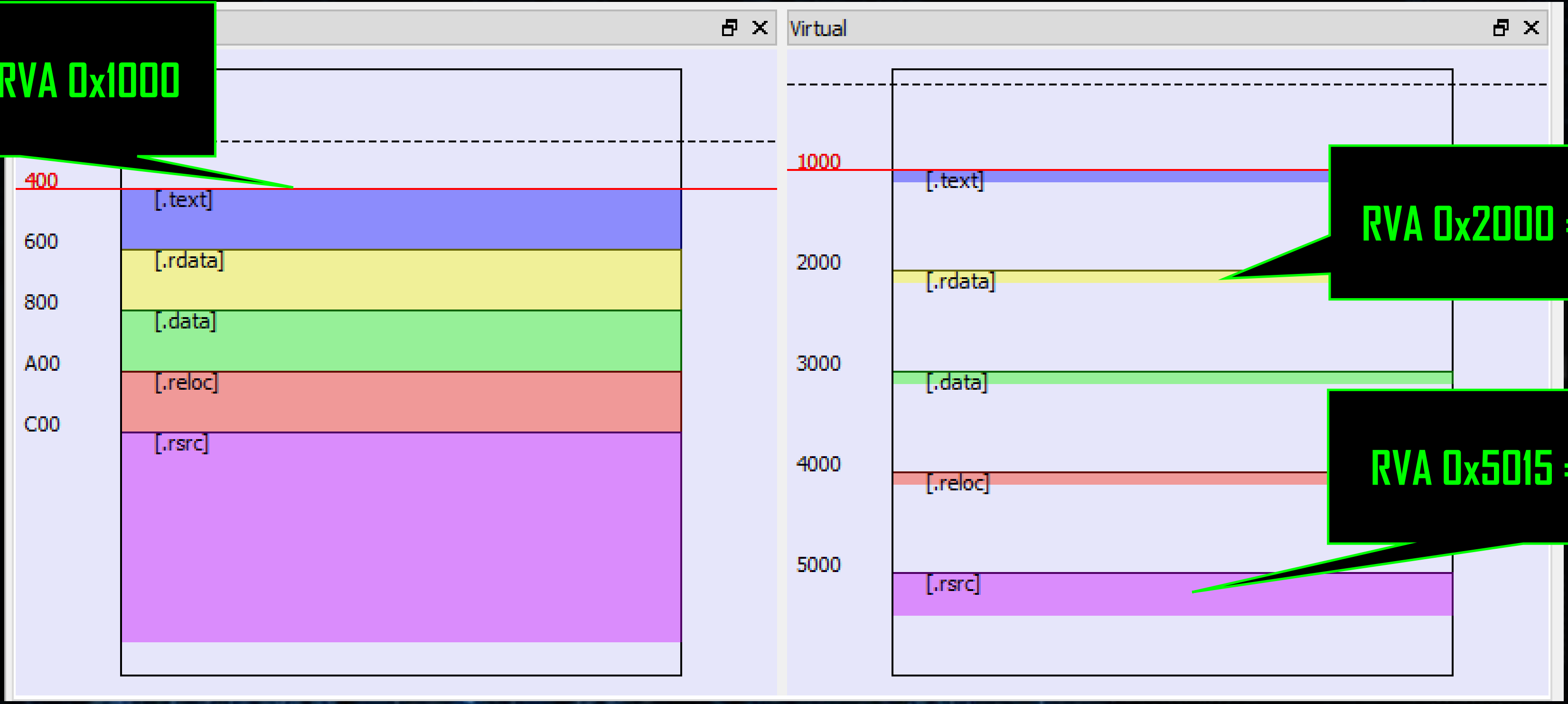
https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/remap.h

Basics of a PE file: caves

- The space reserved for a section is always rounded up to some unit (FileAlignment in a raw format, SectionAlignment in virtual)
- The size of the actual section content may be smaller
- The additional space is unused, and filled with padding. It is called a section cave. A cave in an executable section is often referenced as code cave.
- Caves may be virtual or raw
- Sometimes they may be used for installing code implants

Basics of a PE file: addresses

- Raw addresses (in file) usually correspond to virtual addresses (in memory) and vice versa



Raw 0x400 = RVA 0x1000

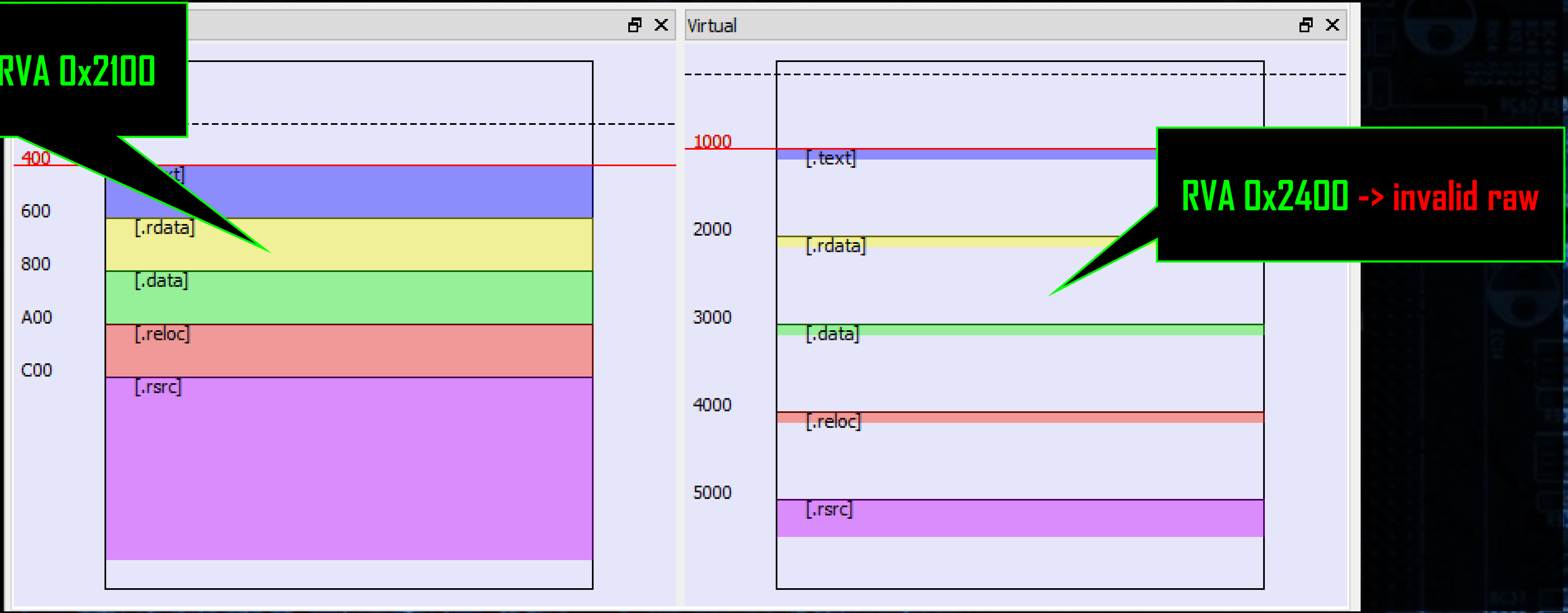
RVA 0x2000 = raw 0x600

RVA 0x5015 = raw 0xC15

- **RVA** : Relative Virtual Address (without Image Base)
- **VA**: absolute Virtual Address (with Image Base)

Basics of a PE file: addresses

- Raw addresses (in file) *usually* correspond to virtual addresses (in memory) and vice versa



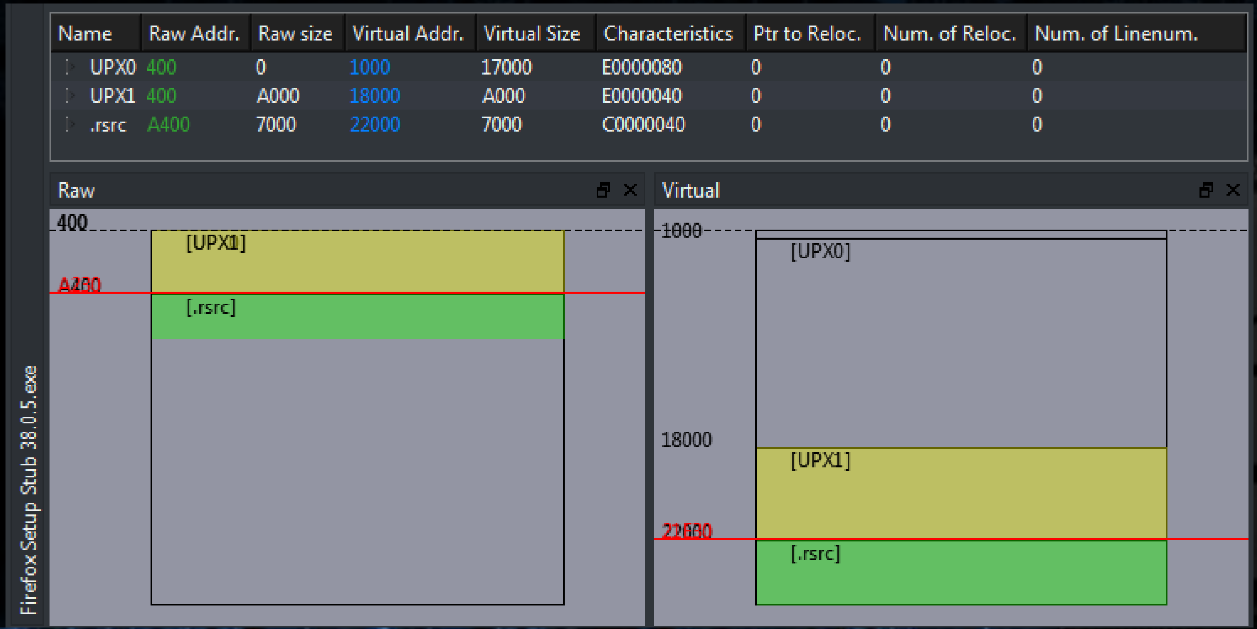
Raw 0x700 = RVA 0x2100

RVA 0x2400 -> invalid raw

- **RVA** : Relative Virtual Address (without Image Base)
- **VA**: absolute Virtual Address (with Image Base)

Basics of a PE file: addresses

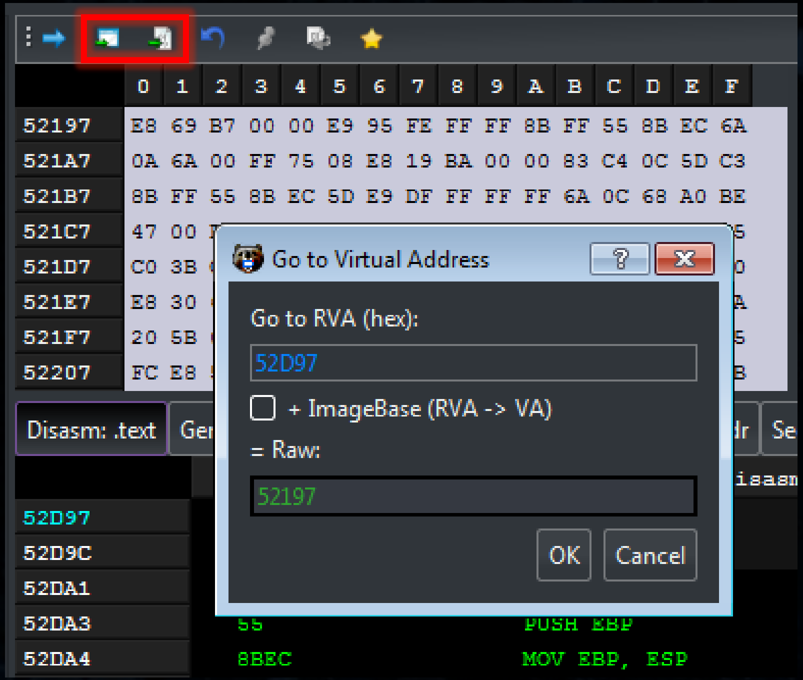
- Raw addresses (in file) *usually* correspond to virtual addresses (in memory) and vice versa
  - However:
    - Some sections can be unpacked in memory and not filled in the file
    - Some addresses may not be mapped (present in the file, but not in the memory image)



Name	Raw Addr.	Raw size	Virtual Addr.	Virtual Size	Characteristics	Ptr to Reloc.	Num. of Reloc.	Num. of Linenum.
UPX0	400	0	1000	17000	E0000080	0	0	0
UPX1	400	A000	18000	A000	E0000040	0	0	0
.rsrc	A400	7000	22000	7000	C0000040	0	0	0

Basics of a PE file: addresses

- Let's open one of our sample PEs in PE-bear and see the section table
- Try converting various addresses from Raw format to Virtual, follow and observe



```
        0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F
52197   E8 69 B7 00 00 E9 95 FE FF FF 8B FF 55 8B EC 6A
521A7   0A 6A 00 FF 75 08 E8 19 BA 00 00 83 C4 0C 5D C3
521B7   8B FF 55 8B EC 5D E9 DF FF FF FF 6A 0C 68 A0 BE
521C7   47 00                                         5
521D7   C0 3B                                         0
521E7   E8 30                                         A
521F7   20 5B                                         5
52207   FC E8                                         B
```

Go to Virtual Address

Go to RVA (hex): 52D97

☐ + ImageBase (RVA -> VA)

= Raw: 52197

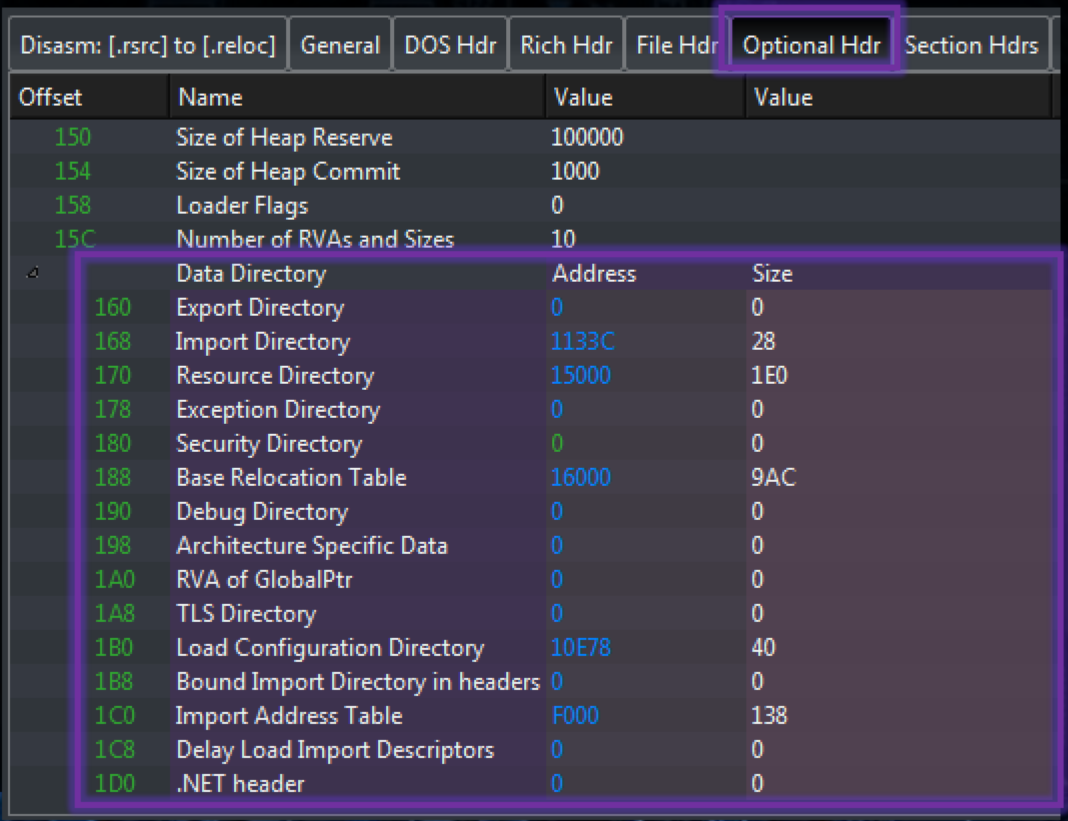
OK Cancel

```
52D97
52D9C
52DA1
52DA3   55      PUSH EBP
52DA4   8BEC    MOV EBP, ESP
```

Exercise time...

Basics of a PE file

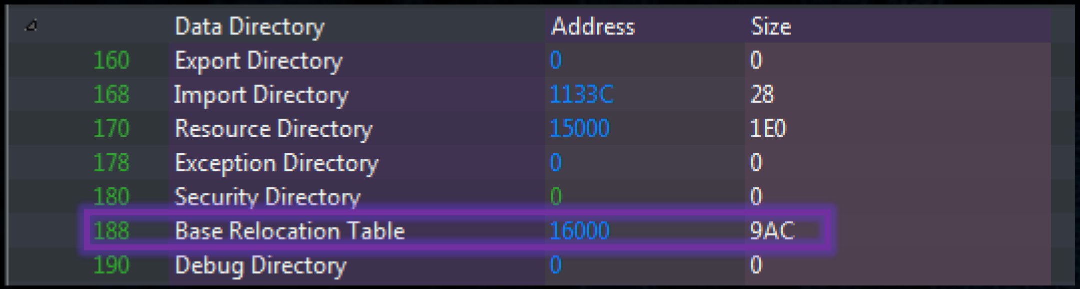
- The most information lies in data directories



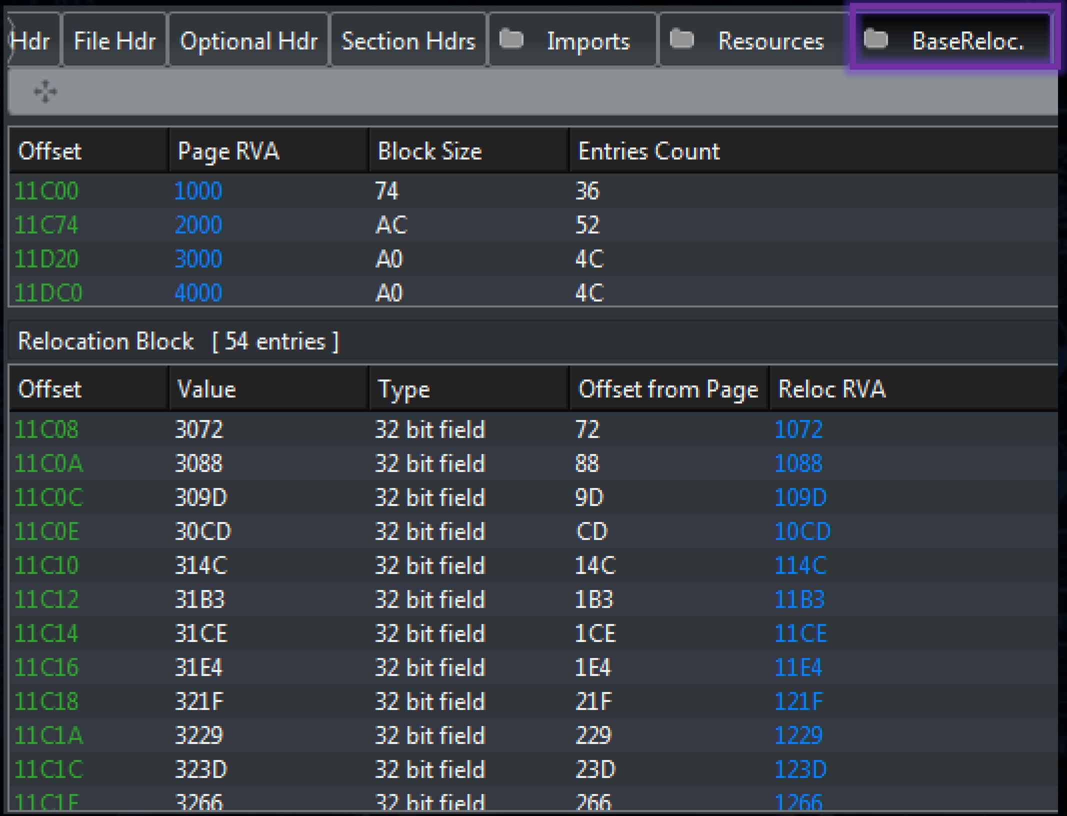
Offset	Name	Value	Value
150	Size of Heap Reserve	100000	
154	Size of Heap Commit	1000	
158	Loader Flags	0	
15C	Number of RVAs and Sizes	10	
	Data Directory	Address	Size
160	Export Directory	0	0
168	Import Directory	1133C	28
170	Resource Directory	15000	1E0
178	Exception Directory	0	0
180	Security Directory	0	0
188	Base Relocation Table	16000	9AC
190	Debug Directory	0	0
198	Architecture Specific Data	0	0
1A0	RVA of GlobalPtr	0	0
1A8	TLS Directory	0	0
1B0	Load Configuration Directory	10E78	40
1B8	Bound Import Directory in headers	0	0
1C0	Import Address Table	F000	138
1C8	Delay Load Import Descriptors	0	0
1D0	.NET header	0	0

Basics of a PE file: Relocation

- Relocation Table



	Data Directory	Address	Size
160	Export Directory	0	0
168	Import Directory	1133C	28
170	Resource Directory	15000	1E0
178	Exception Directory	0	0
180	Security Directory	0	0
188	Base Relocation Table	16000	9AC
190	Debug Directory	0	0



Offset	Page RVA	Block Size	Entries Count
11C00	1000	74	36
11C74	2000	AC	52
11D20	3000	A0	4C
11DC0	4000	A0	4C

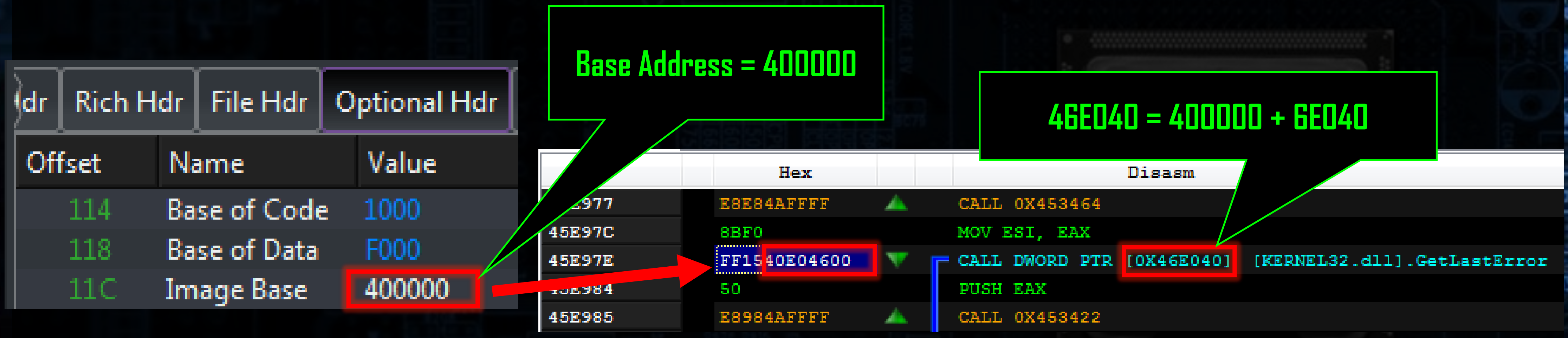
Relocation Block [54 entries]

Offset	Value	Type	Offset from Page	Reloc RVA
11C08	3072	32 bit field	72	1072
11C0A	3088	32 bit field	88	1088
11C0C	309D	32 bit field	9D	109D
11C0E	30CD	32 bit field	CD	10CD
11C10	314C	32 bit field	14C	114C
11C12	31B3	32 bit field	1B3	11B3
11C14	31CE	32 bit field	1CE	11CE
11C16	31E4	32 bit field	1E4	11E4
11C18	321F	32 bit field	21F	121F
11C1A	3229	32 bit field	229	1229
11C1C	323D	32 bit field	23D	123D
11C1E	3266	32 bit field	266	1266

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/relocate.h

Basics of a PE file: Relocation

1. PE comes with some default base address in the header
2. All the absolute addresses inside the PE assume that it was loaded at this base



Offset	Name	Value
114	Base of Code	1000
118	Base of Data	F000
11C	Image Base	400000

Base Address = 400000

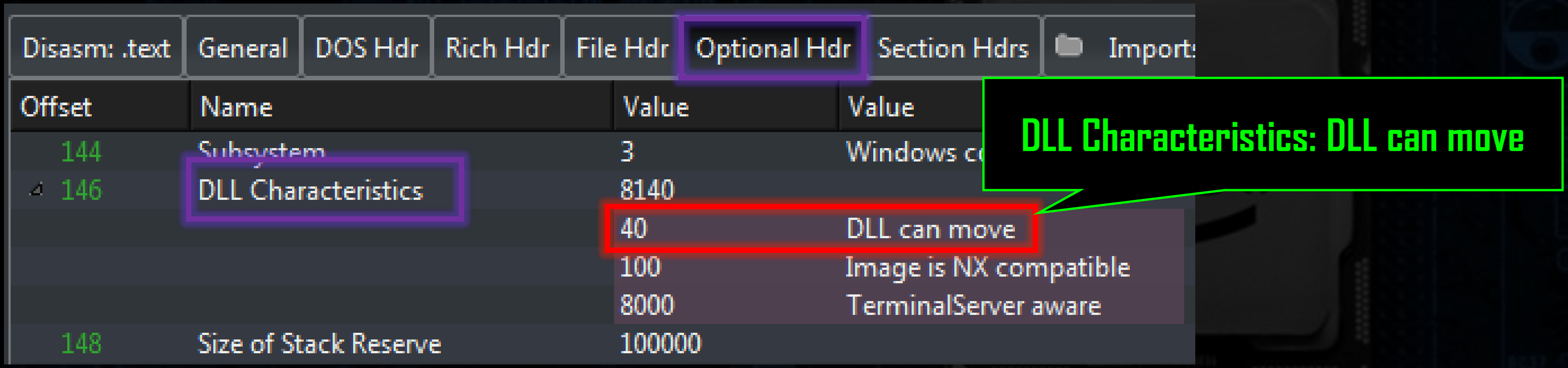
46E040 = 400000 + 6E040

```
        Hex                  Disasm
E977    E8E84AFFFF           CALL 0X453464
45E97C  8BF0                 MOV ESI, EAX
45E97E  FF1540E04600         CALL DWORD PTR [0X46E040]  [KERNEL32.dll].GetLastError
45E984  50                   PUSH EAX
45E985  E8984AFFFF           CALL 0X453422
```

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/relocate.h

Basics of a PE file: Relocation

- In the past EXEs were usually loaded at their default base (only DLLs didn't have to)
- Nowadays most PEs load at a dynamic base (due to ASLR)
- A flag in the header determines if a dynamic base will be used



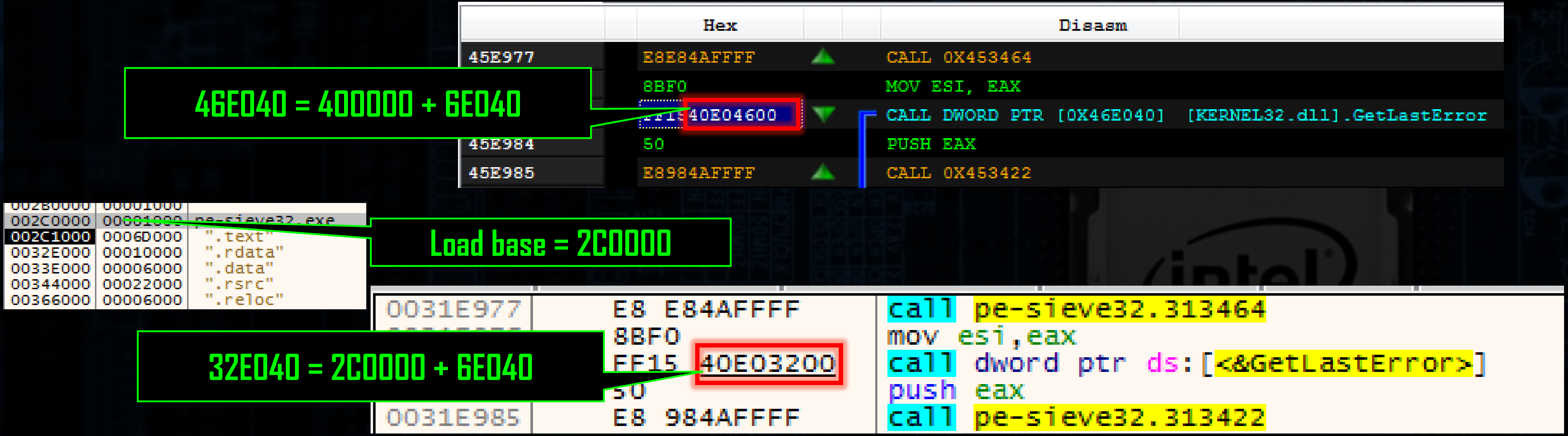
Offset	Name	Value	Value
144	Subsystem	3	Windows c
146	DLL Characteristics	8140	
		40	DLL can move
		100	Image is NX compatible
		8000	TerminalServer aware
148	Size of Stack Reserve	100000	

DLL Characteristics: DLL can move

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/relocate.h

Basics of a PE file: Relocation

- If the PE was loaded at a different base than the one defined in the header, all its fields using absolute addresses must be recalculated (rebased)



```
                      Hex                        Disasm
45E977    E8E84AFFFF      CALL 0X453464
          8BF0            MOV ESI, EAX
          FF1540E04600    CALL DWORD PTR [0X46E040]  [KERNEL32.dll].GetLastError
45E984    50              PUSH EAX
45E985    E8984AFFFF      CALL 0X453422
```

46E040 = 400000 + 6E040

```
002B0000  00001000
002C0000  00001000  pe-sieve32.exe
002C1000  0006D000    ".text"
0032E000  00010000    ".rdata"
0033E000  00006000    ".data"
00344000  00022000    ".rsrc"
00366000  00006000    ".reloc"
```

Load base = 2C0000

```
0031E977   E8 E84AFFFF      call pe-sieve32.313464
           8BF0             mov esi,eax
           FF15 40E03200    call dword ptr ds:[<&GetLastError>]
           50               push eax
0031E985   E8 984AFFFF      call pe-sieve32.313422
```

32E040 = 2C0000 + 6E040

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/relocate.h

Basics of a PE file: Relocation

- How does PE know **where** are the fields that needs to be **rebased**?

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/relocate.h

Basics of a PE file: Relocation

- How does PE know **where** are the fields that needs to be **rebased**?
- They are listed in the Relocation Table!

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/relocate.h

Basics of a PE file: Relocation

- Let's open one of our sample PEs in PE-bear and see the relocation table
- Check the code snippet to see how the relocation table is processed

```
Exercise time...
```

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/relocate.h

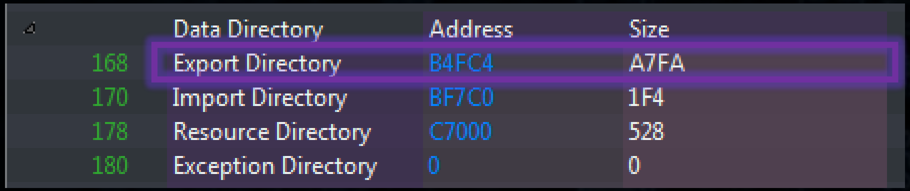
Basics of a PE file: Imports & Exports

Most executables use some functions exported by other modules (external libraries)

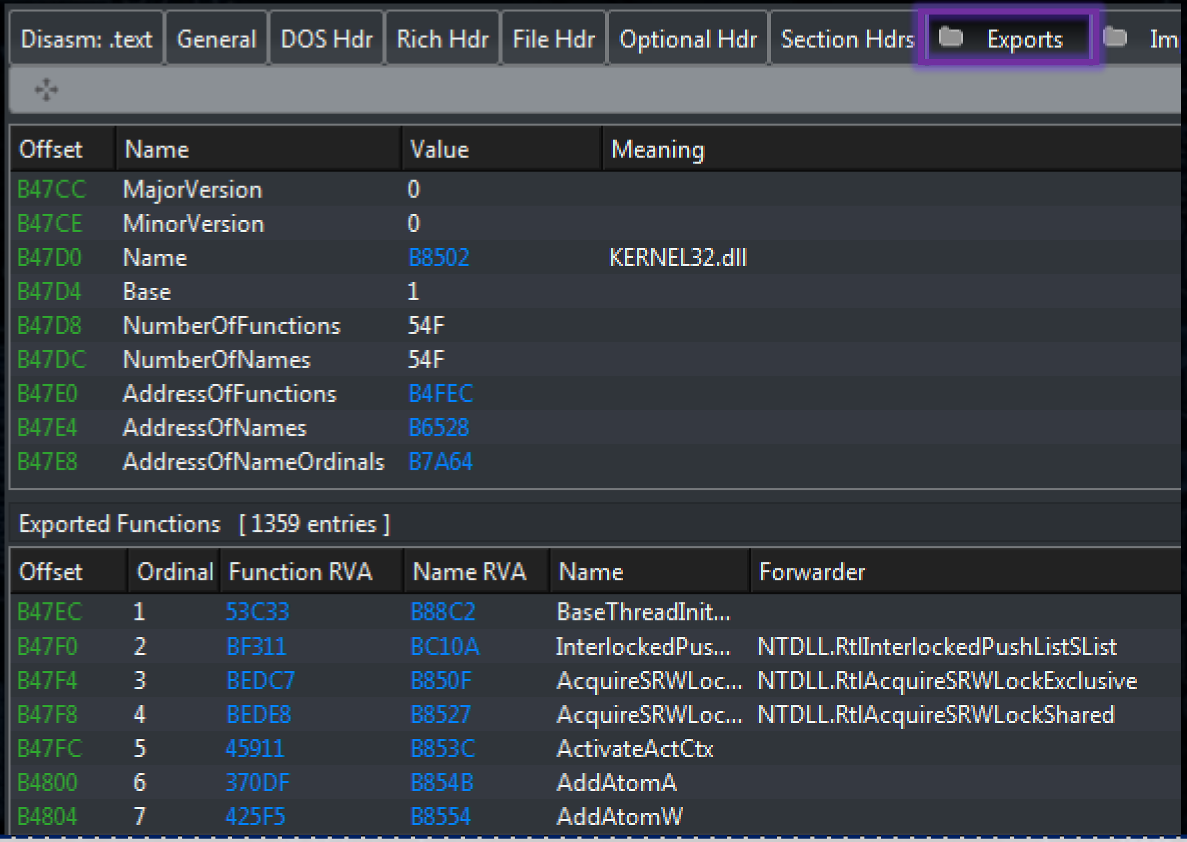
1. If we use a static library, the linker will automatically add the external code into our PE
2. If we use a dynamic library (DLL), the used functions will be listed in the Import Table of our PE, and dynamic linking will be done when the PE is loaded
3. Alternatively, we can load a DLL by ourselves using `LoadLibrary` and fetch the exported function via `GetProcessAddress`

Basics of a PE file: Exports

- Export Table



	Data Directory	Address	Size
168	Export Directory	B4FC4	A7FA
170	Import Directory	BF7C0	1F4
178	Resource Directory	C7000	528
180	Exception Directory	0	0



Offset	Name	Value	Meaning
B47CC	MajorVersion	0	
B47CE	MinorVersion	0	
B47D0	Name	B8502	KERNEL32.dll
B47D4	Base	1	
B47D8	NumberOfFunctions	54F	
B47DC	NumberOfNames	54F	
B47E0	AddressOfFunctions	B4FEC	
B47E4	AddressOfNames	B6528	
B47E8	AddressOfNameOrdinals	B7A64	

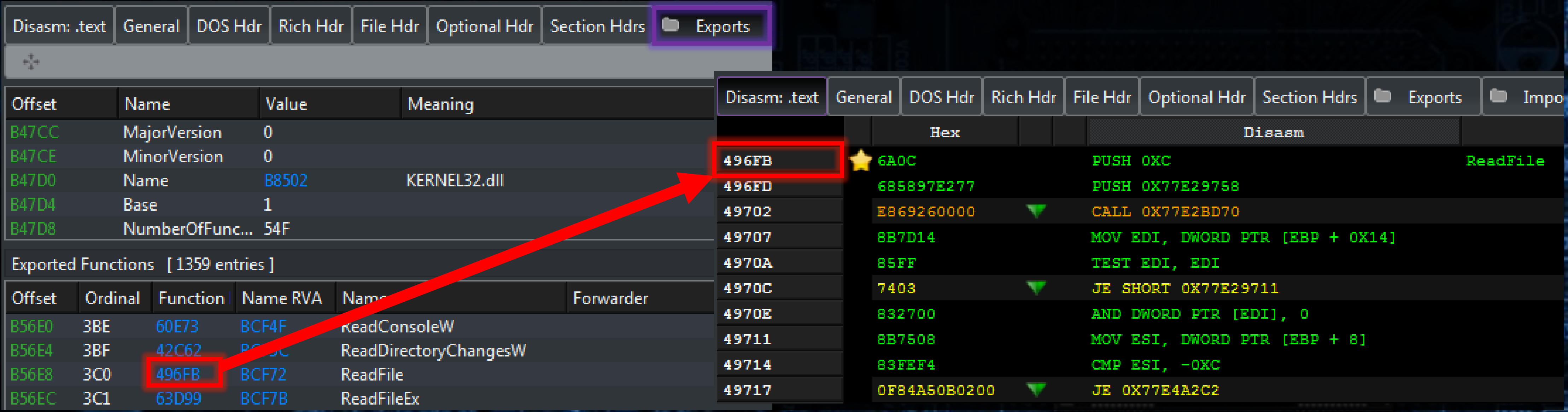
Exported Functions [1359 entries]

Offset	Ordinal	Function RVA	Name RVA	Name	Forwarder
B47EC	1	53C33	B88C2	BaseThreadInit...	
B47F0	2	BF311	BC10A	InterlockedPus...	NTDLL.RtlInterlockedPushListSList
B47F4	3	BEDC7	B850F	AcquireSRWLoc...	NTDLL.RtlAcquireSRWLockExclusive
B47F8	4	BEDE8	B8527	AcquireSRWLoc...	NTDLL.RtlAcquireSRWLockShared
B47FC	5	45911	B853C	ActivateActCtx	
B4800	6	370DF	B854B	AddAtomA	
B4804	7	425F5	B8554	AddAtomW	

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/export_lookup.h

Basics of a PE file: Exports

1. DLLs are libraries of functions for other PEs to use
2. An Export Table is a catalogue allowing to find and use a particular function



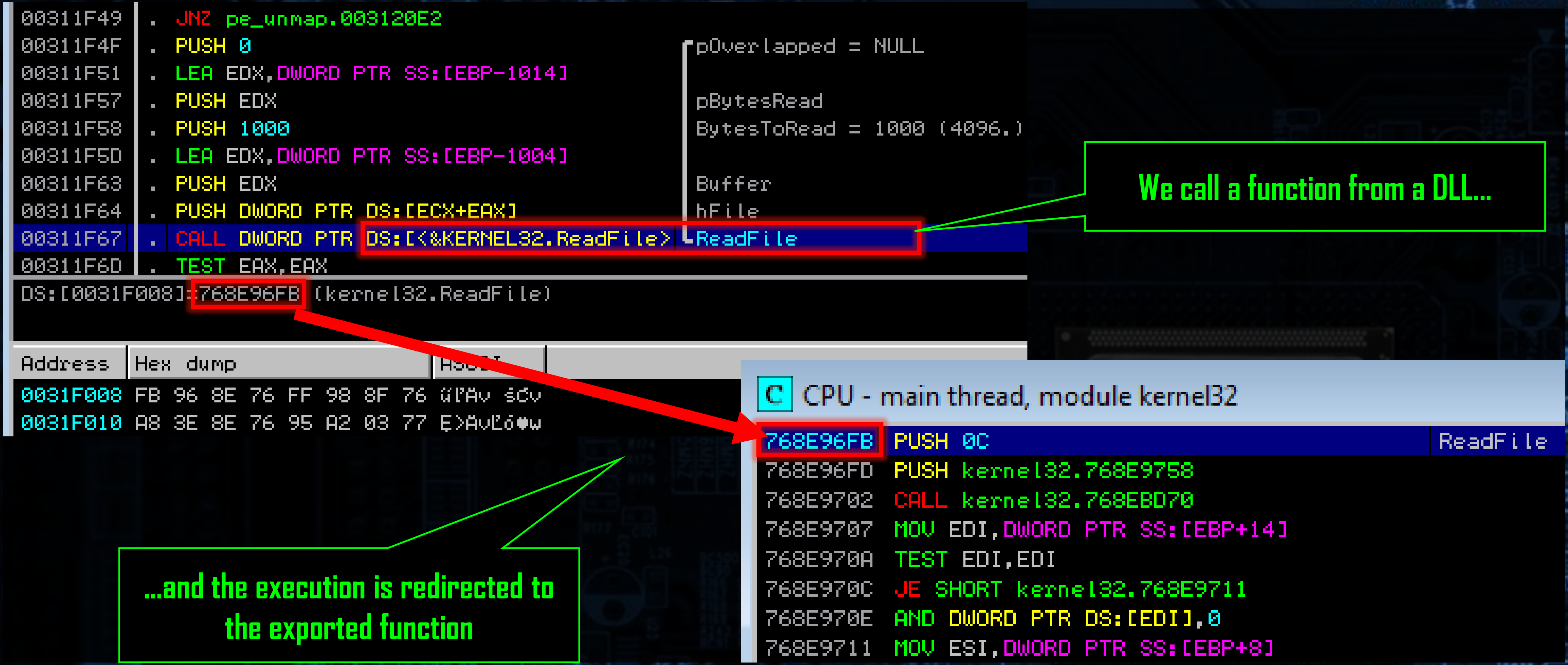
Offset	Name	Value	Meaning
B47CC	MajorVersion	0	
B47CE	MinorVersion	0	
B47D0	Name	B8502	KERNEL32.dll
B47D4	Base	1	
B47D8	NumberOfFunc...	54F	

Exported Functions [1359 entries]

Offset	Ordinal	Function	Name RVA	Name	Forwarder
B56E0	3BE	60E73	BCF4F	ReadConsoleW	
B56E4	3BF	42C62	BCF5C	ReadDirectoryChangesW	
B56E8	3C0	496FB	BCF72	ReadFile	
B56EC	3C1	63D99	BCF7B	ReadFileEx	

	Hex	Disasm	
496FB	6A0C	PUSH 0XC	ReadFile
496FD	685897E277	PUSH 0X77E29758	
49702	E869260000	CALL 0X77E2BD70	
49707	8B7D14	MOV EDI, DWORD PTR [EBP + 0X14]	
4970A	85FF	TEST EDI, EDI	
4970C	7403	JE SHORT 0X77E29711	
4970E	832700	AND DWORD PTR [EDI], 0	
49711	8B7508	MOV ESI, DWORD PTR [EBP + 8]	
49714	83FEF4	CMP ESI, -0XC	
49717	0F84A50B0200	JE 0X77E4A2C2	

Basics of a PE file: Exports



```
00311F49 . JNZ pe_unmap.003120E2
00311F4F . PUSH 0                                  ┌pOverlapped = NULL
00311F51 . LEA EDX,DWORD PTR SS:[EBP-1014]         │
00311F57 . PUSH EDX                                │pBytesRead
00311F58 . PUSH 1000                               │BytesToRead = 1000 (4096.)
00311F5D . LEA EDX,DWORD PTR SS:[EBP-1004]         │
00311F63 . PUSH EDX                                │Buffer
00311F64 . PUSH DWORD PTR DS:[ECX+EAX]             │hFile
00311F67 . CALL DWORD PTR DS:[<&KERNEL32.ReadFile> └ReadFile
00311F6D . TEST EAX,EAX
DS:[0031F008]=768E96FB (kernel32.ReadFile)
```

```
Address  Hex dump                ASCII
0031F008 FB 96 8E 76 FF 98 8F 76 űľÅv šČv
0031F010 A8 3E 8E 76 95 A2 03 77 Ę>ÅvĽó♥w
```

CPU - main thread, module kernel32

```
768E96FB PUSH 0C                                   ReadFile
768E96FD PUSH kernel32.768E9758
768E9702 CALL kernel32.768EBD70
768E9707 MOV EDI,DWORD PTR SS:[EBP+14]
768E970A TEST EDI,EDI
768E970C JE SHORT kernel32.768E9711
768E970E AND DWORD PTR DS:[EDI],0
768E9711 MOV ESI,DWORD PTR SS:[EBP+8]
```

We call a function from a DLL...

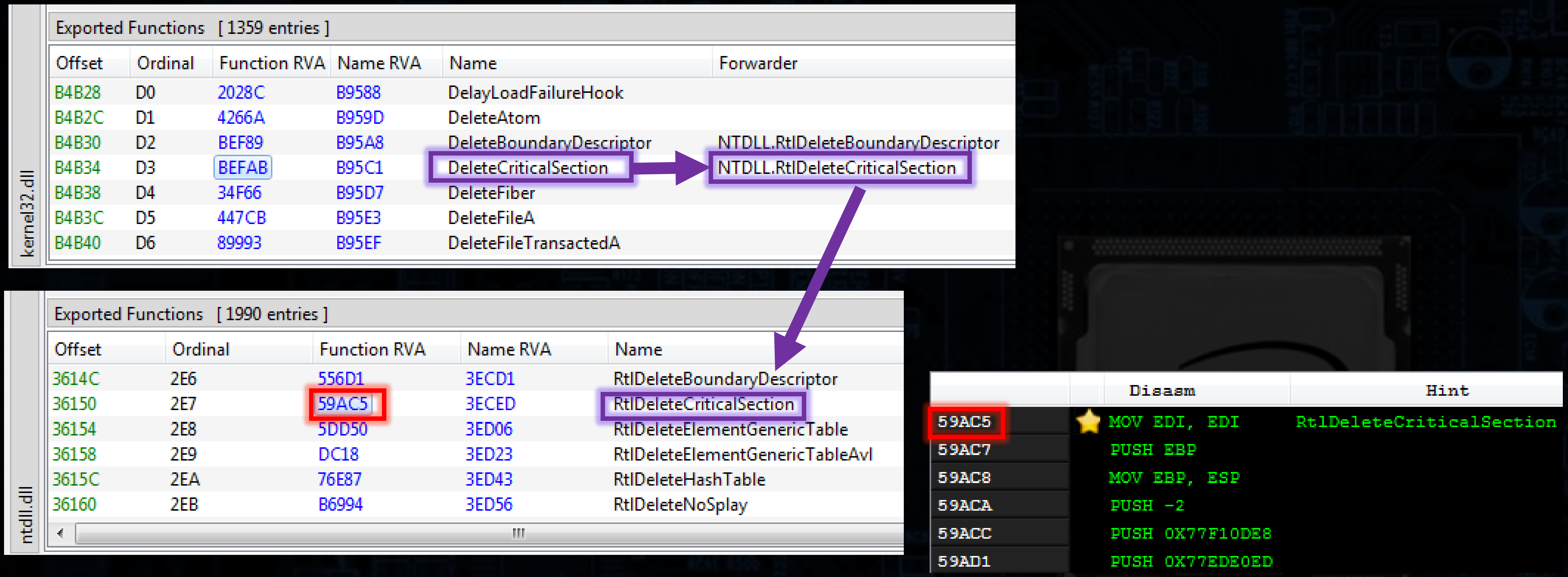
...and the execution is redirected to the exported function

Basics of a PE file: Exports

1. Functions can be exported by a name or by ordinal (a number)
2. Some exports can be forwarded (pointing to other functions, in other DLLs)

Basics of a PE file: Exports

- Forwarded functions



kernel32.dll

Exported Functions [1359 entries]

Offset	Ordinal	Function RVA	Name RVA	Name	Forwarder
B4B28	D0	2028C	B9588	DelayLoadFailureHook	
B4B2C	D1	4266A	B959D	DeleteAtom	
B4B30	D2	BEF89	B95A8	DeleteBoundaryDescriptor	NTDLL.RtlDeleteBoundaryDescriptor
B4B34	D3	BEFAB	B95C1	DeleteCriticalSection	NTDLL.RtlDeleteCriticalSection
B4B38	D4	34F66	B95D7	DeleteFiber	
B4B3C	D5	447CB	B95E3	DeleteFileA	
B4B40	D6	89993	B95EF	DeleteFileTransactedA	

ntdll.dll

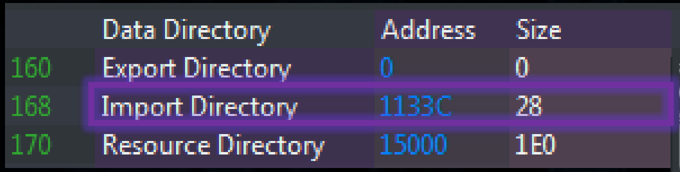
Exported Functions [1990 entries]

Offset	Ordinal	Function RVA	Name RVA	Name
3614C	2E6	556D1	3ECD1	RtlDeleteBoundaryDescriptor
36150	2E7	59AC5	3ECED	RtlDeleteCriticalSection
36154	2E8	5DD50	3ED06	RtlDeleteElementGenericTable
36158	2E9	DC18	3ED23	RtlDeleteElementGenericTableAvl
3615C	2EA	76E87	3ED43	RtlDeleteHashTable
36160	2EB	B6994	3ED56	RtlDeleteNoSplay

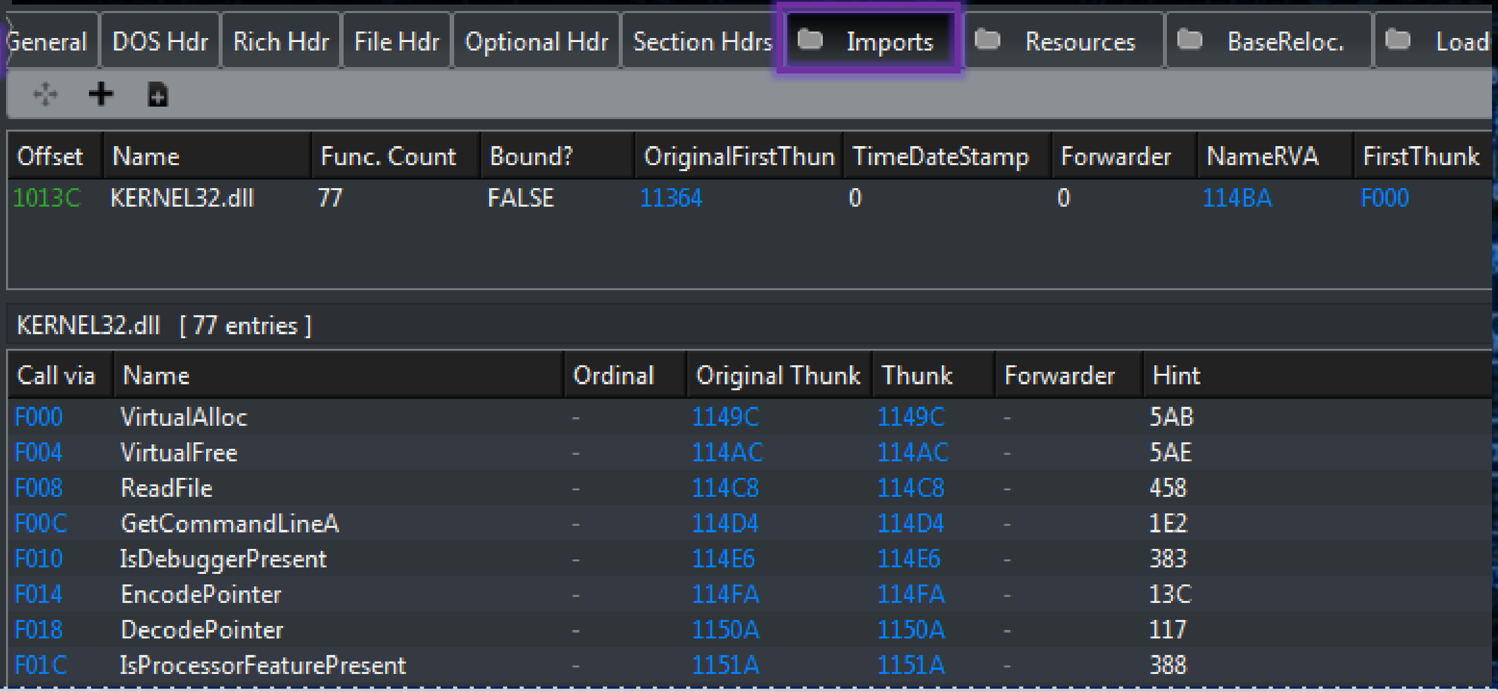
	Disasm	Hint
59AC5	MOV EDI, EDI	RtlDeleteCriticalSection
59AC7	PUSH EBP	
59AC8	MOV EBP, ESP	
59ACA	PUSH -2	
59ACC	PUSH 0X77F10DE8	
59AD1	PUSH 0X77EDE0ED	

Basics of a PE file: Imports

- Import Table



	Data Directory	Address	Size
160	Export Directory	0	0
168	Import Directory	1133C	28
170	Resource Directory	15000	1E0



Offset	Name	Func. Count	Bound?	OriginalFirstThun	TimeDateStamp	Forwarder	NameRVA	FirstThunk
1013C	KERNEL32.dll	77	FALSE	11364	0	0	114BA	F000

KERNEL32.dll [77 entries]

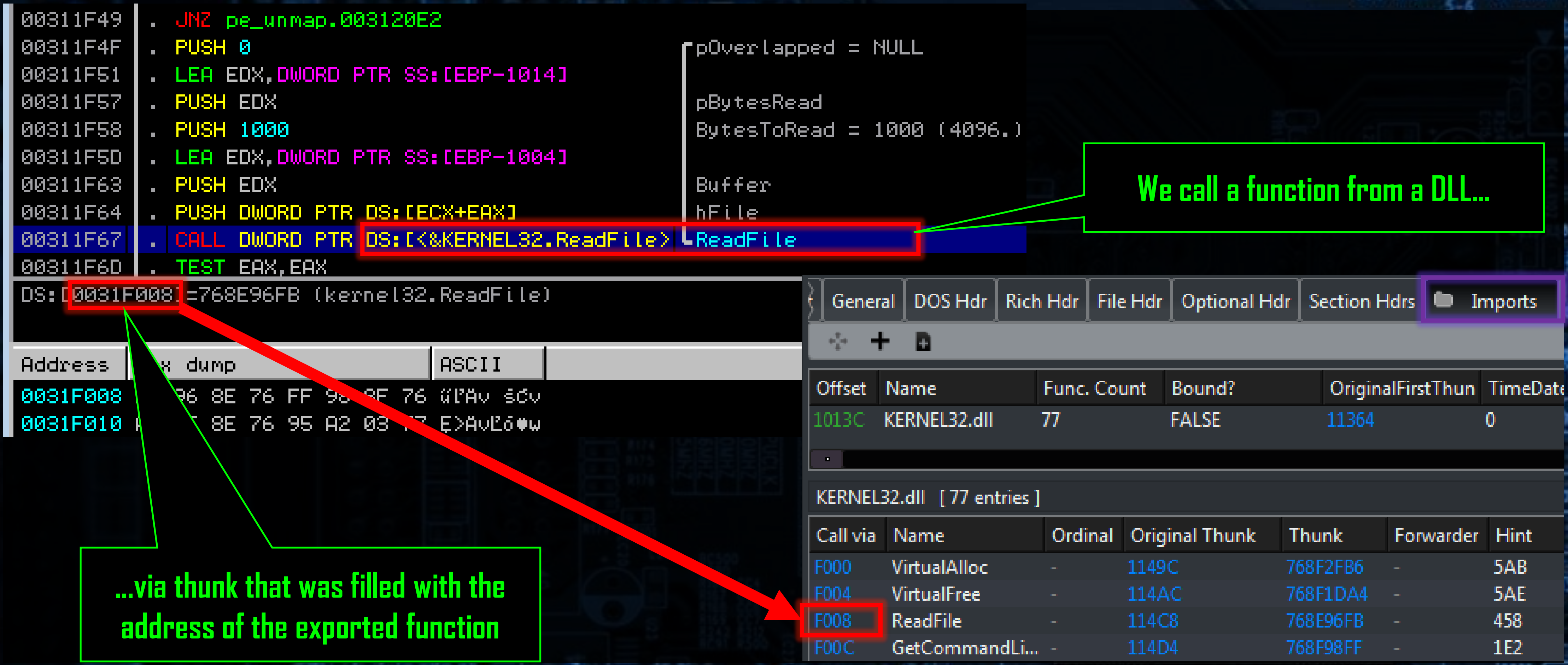
Call via	Name	Ordinal	Original Thunk	Thunk	Forwarder	Hint
F000	VirtualAlloc	-	1149C	1149C	-	5AB
F004	VirtualFree	-	114AC	114AC	-	5AE
F008	ReadFile	-	114C8	114C8	-	458
F00C	GetCommandLineA	-	114D4	114D4	-	1E2
F010	IsDebuggerPresent	-	114E6	114E6	-	383
F014	EncodePointer	-	114FA	114FA	-	13C
F018	DecodePointer	-	1150A	1150A	-	117
F01C	IsProcessorFeaturePresent	-	1151A	1151A	-	388

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/imports_load.h

Basics of a PE file: Imports

- Dynamic linking is done when a PE is loaded
- The loader walks through the Import Table of the PE
  - loads needed DLLs
  - searches the imported functions in the export table of the DLL
  - fills the thunks via which the PE is going to make calls to the exported functions with appropriate addresses

Basics of a PE file: Imports



```
00311F49 | . JNZ pe_unmap.003120E2
00311F4F | . PUSH 0                                   ┌pOverlapped = NULL
00311F51 | . LEA EDX,DWORD PTR SS:[EBP-1014]          │
00311F57 | . PUSH EDX                                 │pBytesRead
00311F58 | . PUSH 1000                                │BytesToRead = 1000 (4096.)
00311F5D | . LEA EDX,DWORD PTR SS:[EBP-1004]          │
00311F63 | . PUSH EDX                                 │Buffer
00311F64 | . PUSH DWORD PTR DS:[ECX+EAX]              │hFile
00311F67 | . CALL DWORD PTR DS:[<&KERNEL32.ReadFile>  └ReadFile
00311F6D | . TEST EAX,EAX
DS:[0031F008]=768E96FB (kernel32.ReadFile)
```

```
Address   Hex dump                  ASCII
0031F008   96 8E 76 FF 98 8F 76     űĽÄv šĆv
0031F010      8E 76 95 A2 03 77     Ę>ÄvĽó♦w
```

Offset	Name	Func. Count	Bound?	OriginalFirstThun	TimeDate
1013C	KERNEL32.dll	77	FALSE	11364	0

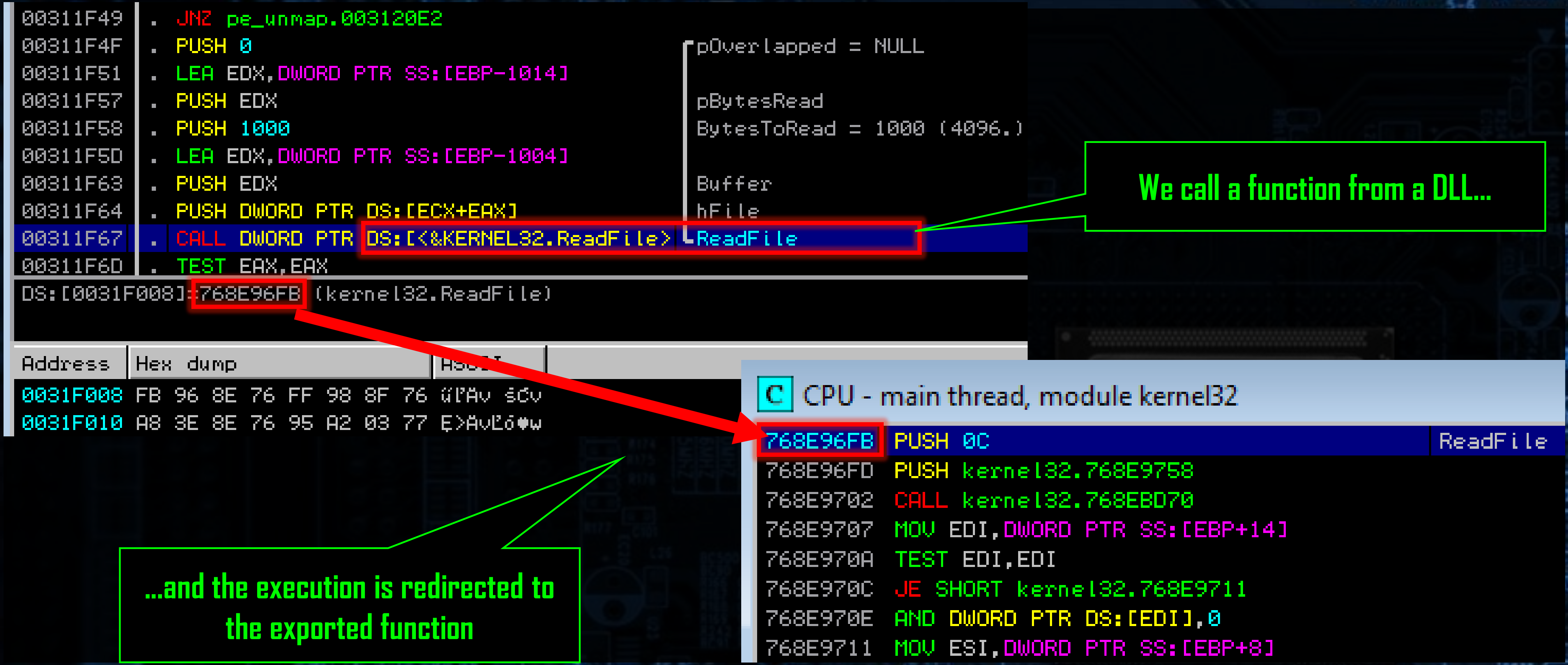
KERNEL32.dll [77 entries]

Call via	Name	Ordinal	Original Thunk	Thunk	Forwarder	Hint
F000	VirtualAlloc	-	1149C	768F2FB6	-	5AB
F004	VirtualFree	-	114AC	768F1DA4	-	5AE
F008	ReadFile	-	114C8	768E96FB	-	458
F00C	GetCommandLi...	-	114D4	768F98FF	-	1E2

We call a function from a DLL...

...via thunk that was filled with the address of the exported function

Basics of a PE file: Imports



```
00311F49 │ . JNZ pe_unmap.003120E2
00311F4F │ . PUSH 0                                          ┌pOverlapped = NULL
00311F51 │ . LEA EDX,DWORD PTR SS:[EBP-1014]                 │
00311F57 │ . PUSH EDX                                        │pBytesRead
00311F58 │ . PUSH 1000                                       │BytesToRead = 1000 (4096.)
00311F5D │ . LEA EDX,DWORD PTR SS:[EBP-1004]                 │
00311F63 │ . PUSH EDX                                        │Buffer
00311F64 │ . PUSH DWORD PTR DS:[ECX+EAX]                     │hFile
00311F67 │ . CALL DWORD PTR DS:[<&KERNEL32.ReadFile>]        └ReadFile
00311F6D │ . TEST EAX,EAX
DS:[0031F008]=768E96FB (kernel32.ReadFile)
```

```
Address   Hex dump                 ASCII
0031F008 FB 96 8E 76 FF 98 8F 76 űľAv śČv
0031F010 A8 3E 8E 76 95 A2 03 77 Ę>AvĽó♥w
```

CPU - main thread, module kernel32

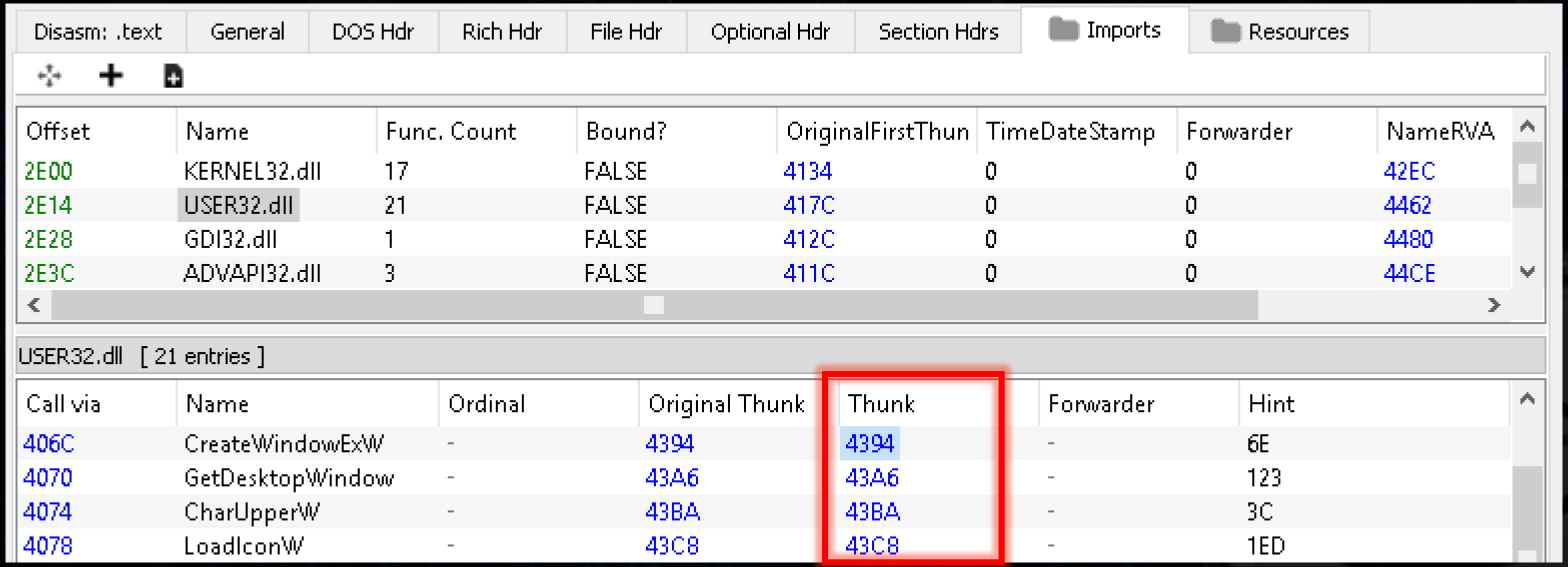
```
768E96FB  PUSH 0C                                  ReadFile
768E96FD  PUSH kernel32.768E9758
768E9702  CALL kernel32.768EBD70
768E9707  MOV EDI,DWORD PTR SS:[EBP+14]
768E970A  TEST EDI,EDI
768E970C  JE SHORT kernel32.768E9711
768E970E  AND DWORD PTR DS:[EDI],0
768E9711  MOV ESI,DWORD PTR SS:[EBP+8]
```

We call a function from a DLL…

…and the execution is redirected to the exported function

Basics of a PE file: Imports

- Raw: before filling imports



Offset	Name	Func. Count	Bound?	OriginalFirstThun	TimeDateStamp	Forwarder	NameRVA
2E00	KERNEL32.dll	17	FALSE	4134	0	0	42EC
2E14	USER32.dll	21	FALSE	417C	0	0	4462
2E28	GDI32.dll	1	FALSE	412C	0	0	4480
2E3C	ADVAPI32.dll	3	FALSE	411C	0	0	44CE

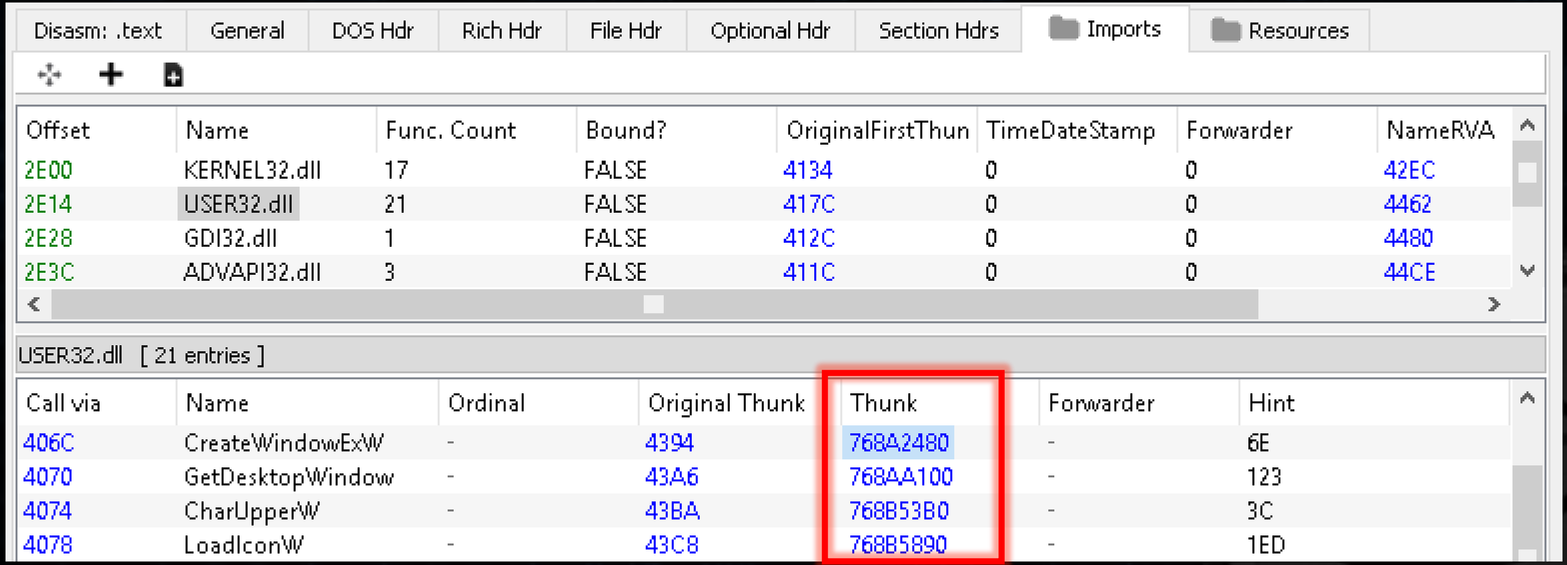
USER32.dll [21 entries]

Call via	Name	Ordinal	Original Thunk	Thunk	Forwarder	Hint
406C	CreateWindowExW	-	4394	4394	-	6E
4070	GetDesktopWindow	-	43A6	43A6	-	123
4074	CharUpperW	-	43BA	43BA	-	3C
4078	LoadIconW	-	43C8	43C8	-	1ED

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/imports_load.h

Basics of a PE file: Imports

- Loaded: after filling imports – thunks are filled with addresses of exported functions



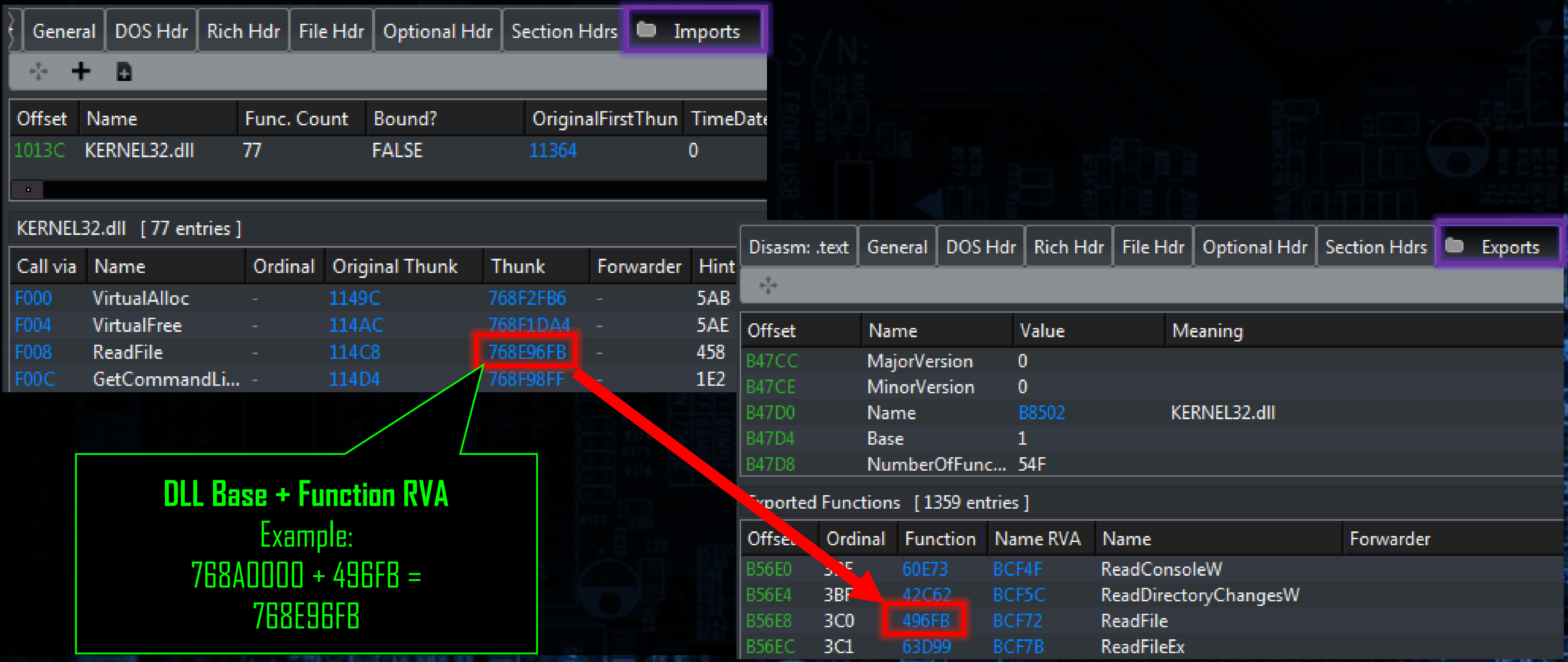
Offset	Name	Func. Count	Bound?	OriginalFirstThun	TimeDateStamp	Forwarder	NameRVA
2E00	KERNEL32.dll	17	FALSE	4134	0	0	42EC
2E14	USER32.dll	21	FALSE	417C	0	0	4462
2E28	GDI32.dll	1	FALSE	412C	0	0	4480
2E3C	ADVAPI32.dll	3	FALSE	411C	0	0	44CE

USER32.dll [21 entries]

Call via	Name	Ordinal	Original Thunk	Thunk	Forwarder	Hint
406C	CreateWindowExW	-	4394	768A2480	-	6E
4070	GetDesktopWindow	-	43A6	768AA100	-	123
4074	CharUpperW	-	43BA	768B53B0	-	3C
4078	LoadIconW	-	43C8	768B5890	-	1ED

https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/imports_load.h

Basics of a PE file: Imports



Offset	Name	Func. Count	Bound?	OriginalFirstThun	TimeDate
1013C	KERNEL32.dll	77	FALSE	11364	0

KERNEL32.dll [77 entries]

Call via	Name	Ordinal	Original Thunk	Thunk	Forwarder	Hint
F000	VirtualAlloc	-	1149C	768F2FB6	-	5AB
F004	VirtualFree	-	114AC	768F1DA4	-	5AE
F008	ReadFile	-	114C8	768E96FB	-	458
F00C	GetCommandLi...	-	114D4	768F98FF	-	1E2

Offset	Name	Value	Meaning
B47CC	MajorVersion	0	
B47CE	MinorVersion	0	
B47D0	Name	B8502	KERNEL32.dll
B47D4	Base	1	
B47D8	NumberOfFunc...	54F	

Exported Functions [1359 entries]

Offset	Ordinal	Function	Name RVA	Name	Forwarder
B56E0	3BE	60E73	BCF4F	ReadConsoleW	
B56E4	3BF	42C62	BCF5C	ReadDirectoryChangesW	
B56E8	3C0	496FB	BCF72	ReadFile	
B56EC	3C1	63D99	BCF7B	ReadFileEx	

DLL Base + Function RVA

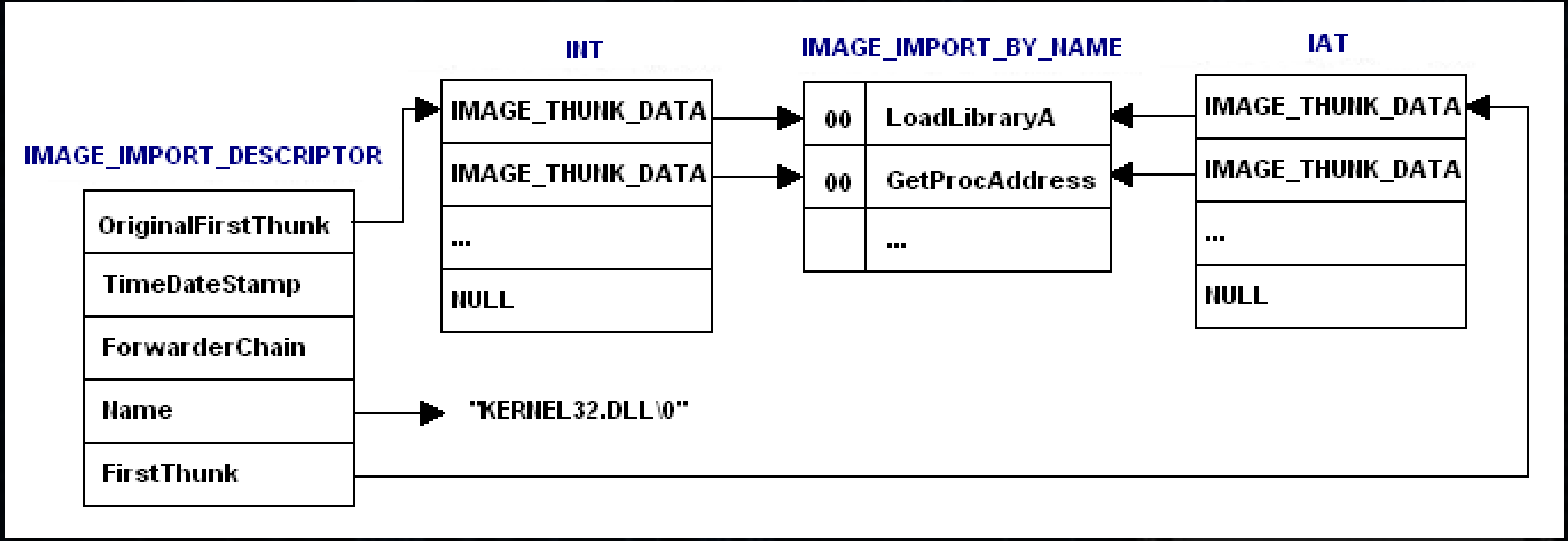
Example:

768A0000 + 496FB =

768E96FB

Basics of a PE file: Imports

- Import Table: structure



https://github.com/hasherezade/malware_training_vol1/blob/main/exercises/module1/lesson2_pe/pe_snippets/imports_load.h

Basics of a PE file: Imports

- Let's open one of our sample PEs in PE-bear and see the import table. Find the corresponding DLLs and their exports.
- Check the code snippets to see how the import and export tables are processed

```
Exercise time...
```

Exercise

- Compile the given code of a custom PE loader and get familiar with it
  - https://github.com/hasherezade/malware_training_vol1/tree/main/exercises/module1/lesson2_pe

Further readings...

- MSDN documentation:
  - https://docs.microsoft.com/en-us/windows/win32/debug/pe-format
- Classic articles about PE by Matt Pietrek:
  - https://bytepointer.com/resources/pietrek_in_depth_look_into_pe_format_pt1.htm -
  - https://bytepointer.com/resources/pietrek_in_depth_look_into_pe_format_pt2.htm
  - https://docs.microsoft.com/en-us/previous-versions/ms809762(v=msdn.10)?redirectedfrom=MSDN