Public Preview Version

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Windows Memory Dump Analysis Accelerated

Version 5.0

Part 1: Process User Space

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Software Diagnostics Services

Prerequisites

WinDbg Commands

We use these boxes to introduce WinDbg commands used in practice exercises

Basic Windows troubleshooting

Training Goals

- Part 1A: Review fundamentals
- Part 1B: Learn how to analyze process dumps
- Part 2A: Review fundamentals
- Part 2B: Learn how to analyze kernel dumps
- Part 2C: Learn how to analyze complete (physical) and active dumps
- Part 2D: Learn how to analyze minidumps

Training Principles

- Talk only about what I can show
- Lots of pictures
- Lots of examples
- Original content and examples

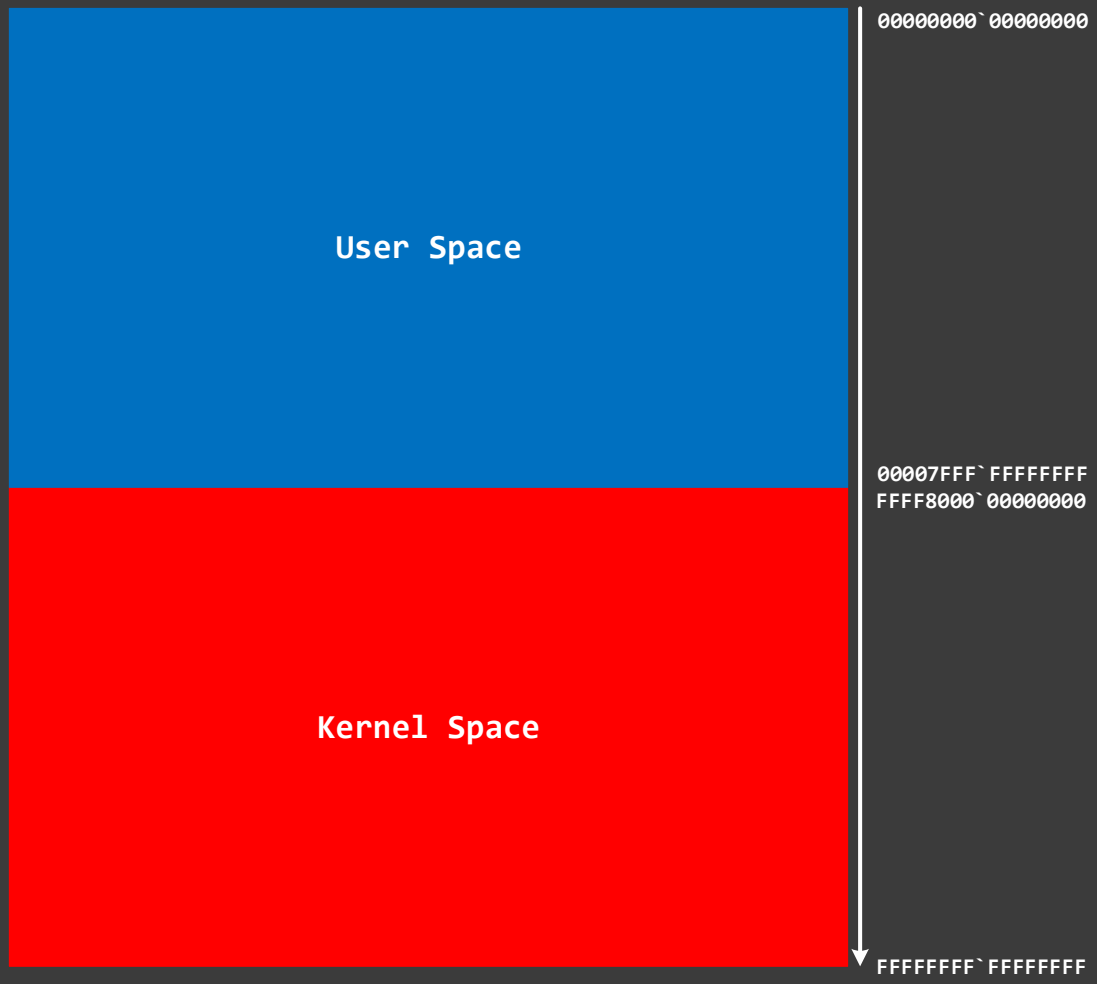
Coverage (Part 1)

- Windows 10 x64
- Both x64 and x86 code, WOW64
- Preliminary .NET analysis
- Process memory dumps
- Crashes, hangs, memory and handle leaks, CPU spikes

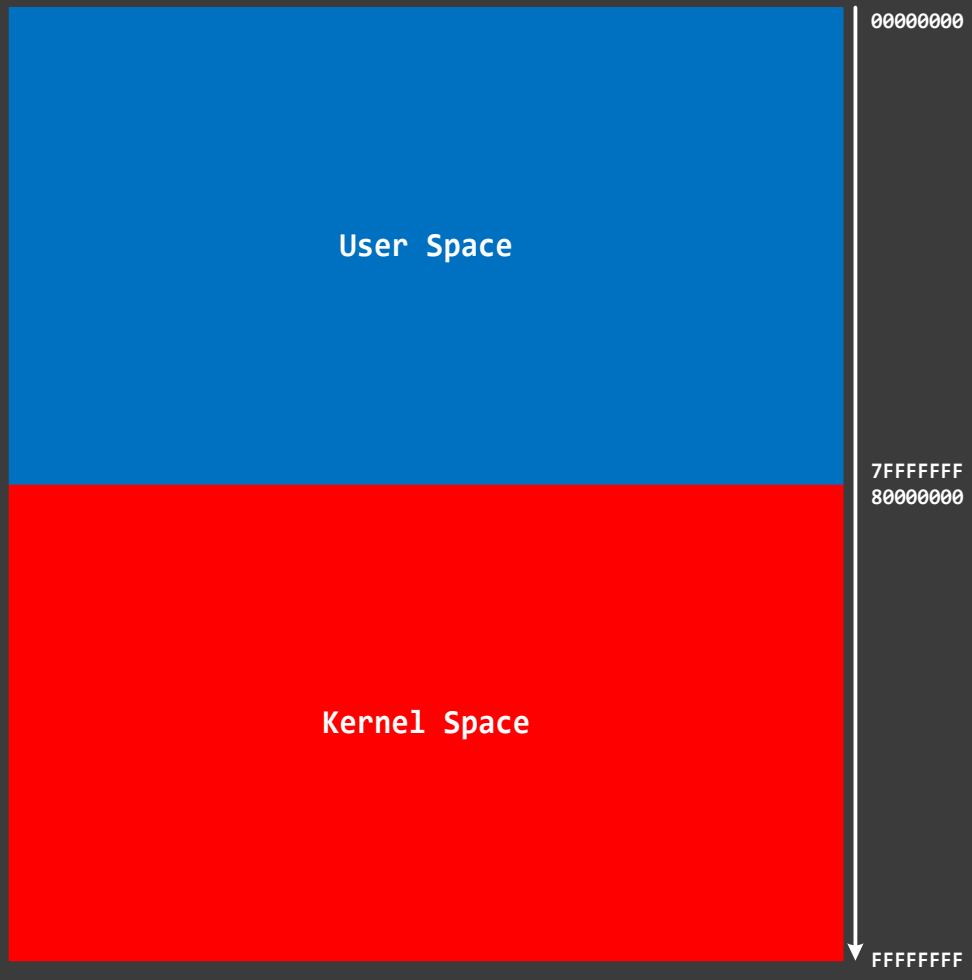
Most of exercises are focused on x64 code. For their x86 equivalents from older Windows versions please refer to the previous edition of this course.

Part 1A: Fundamentals

Process Space (x64)

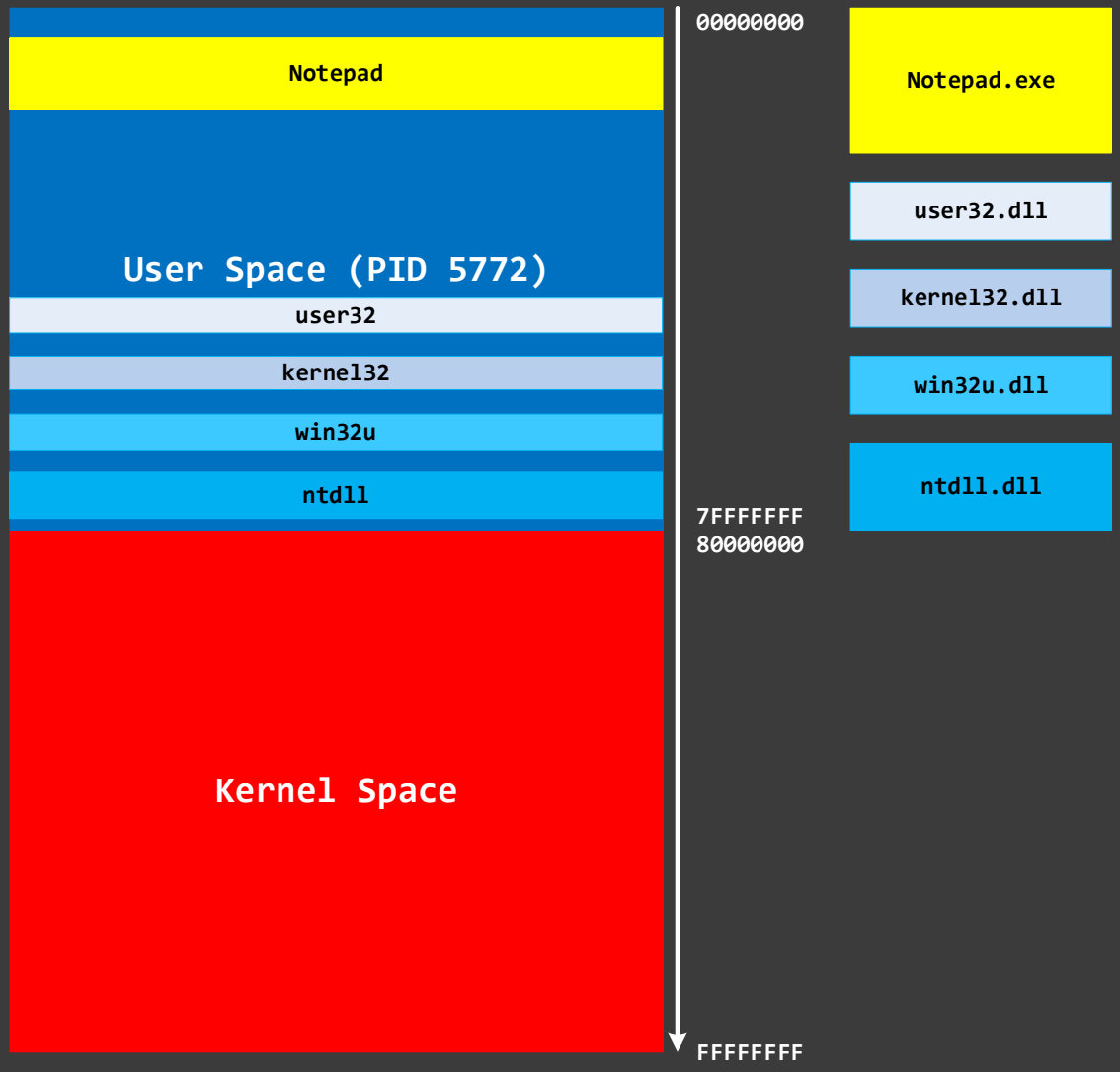


Process Space (x86)

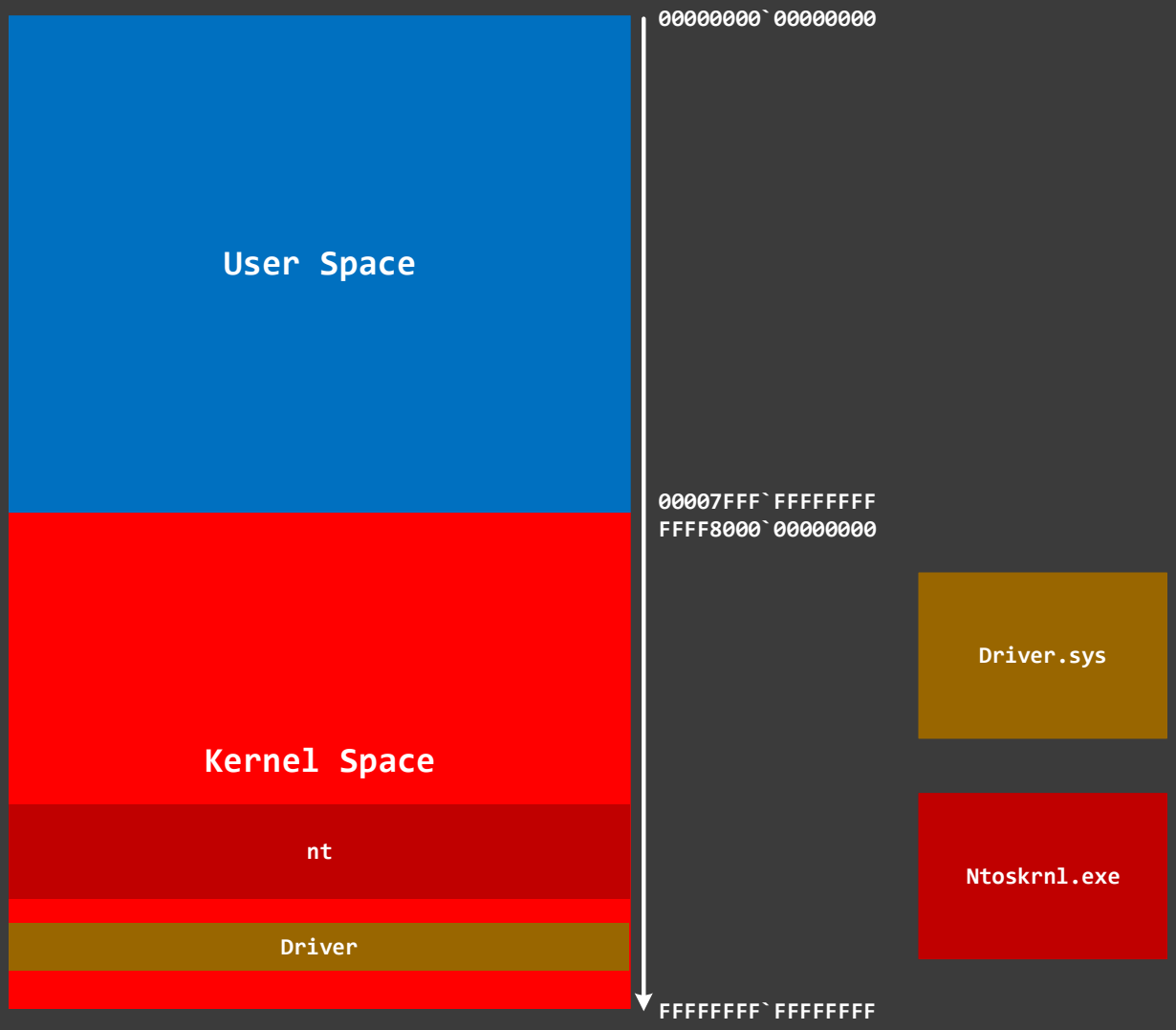


Application/Process/Module (x64)

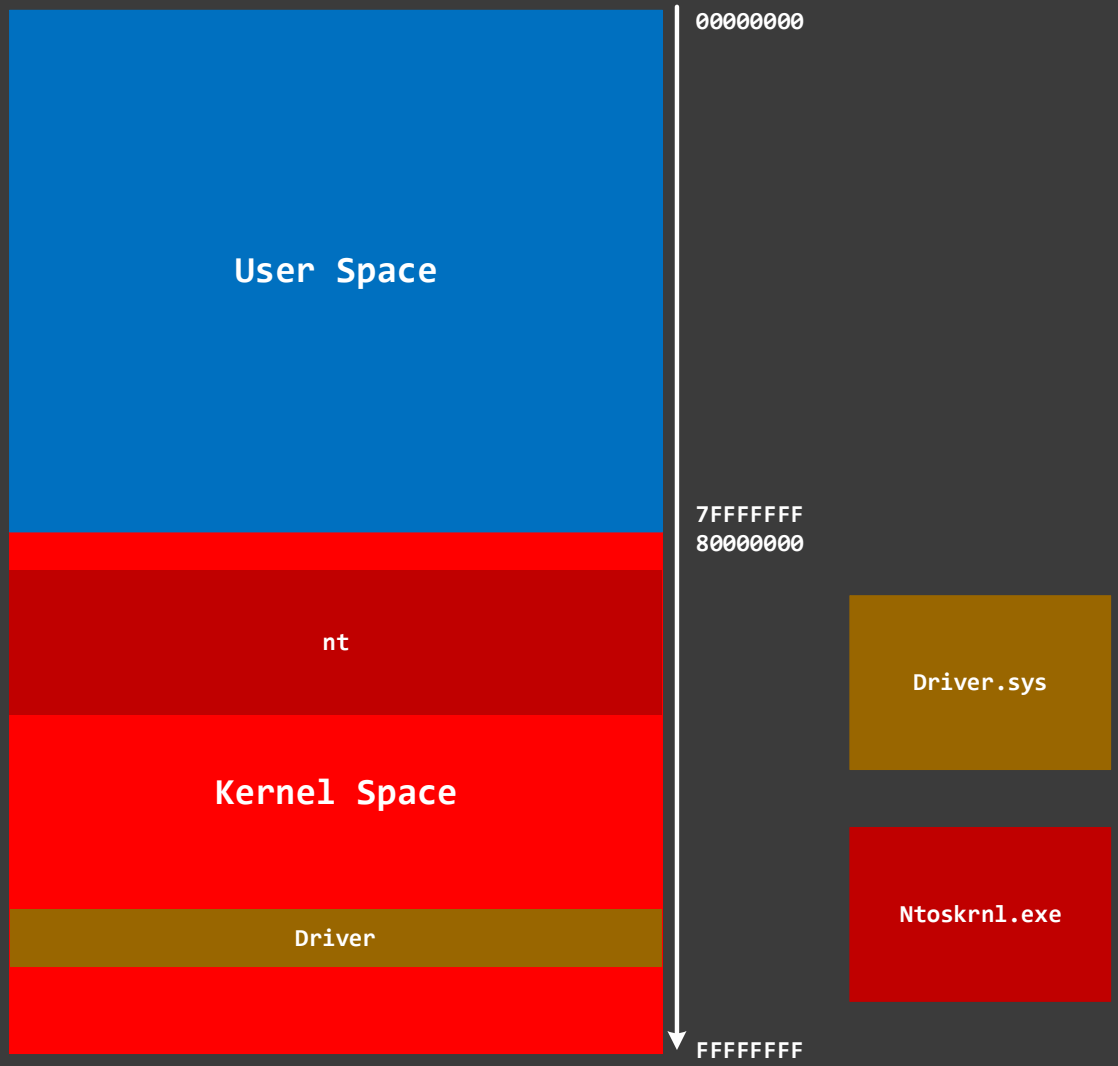
Application/Process/Module (x86)



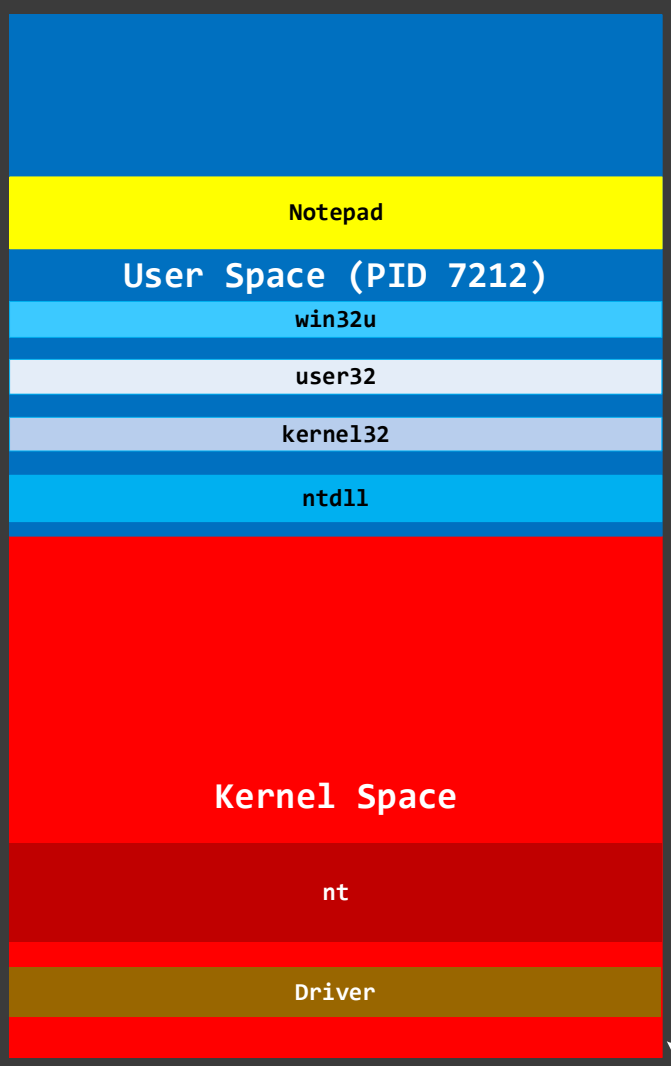
OS Kernel/Driver/Module (x64)



OS Kernel/Driver/Module (x86)



Process Virtual Space (x64)



00000000`00000000

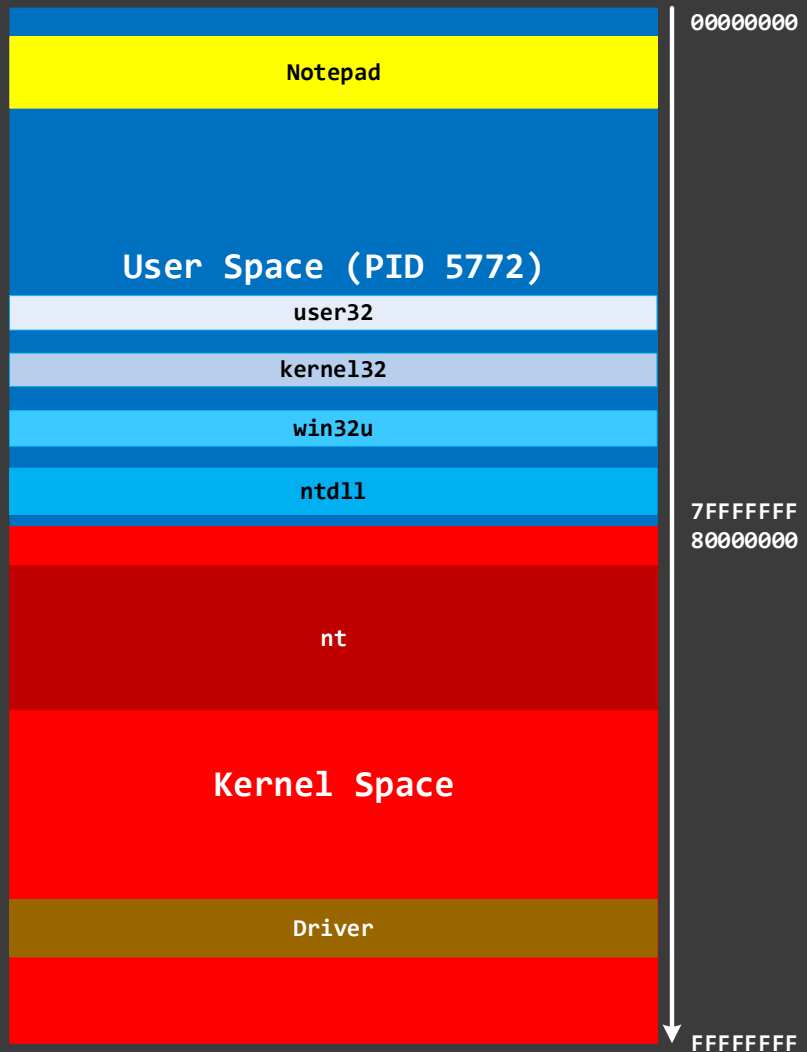
00007FF6`00000000

00007FFF`FFFFFFFF
FFFF8000`00000000

FFFFFFFF`FFFFFFFF

00000000`00000000 ...
FFFFFFFF`FFFFFFFF

Process Virtual Space (x86)



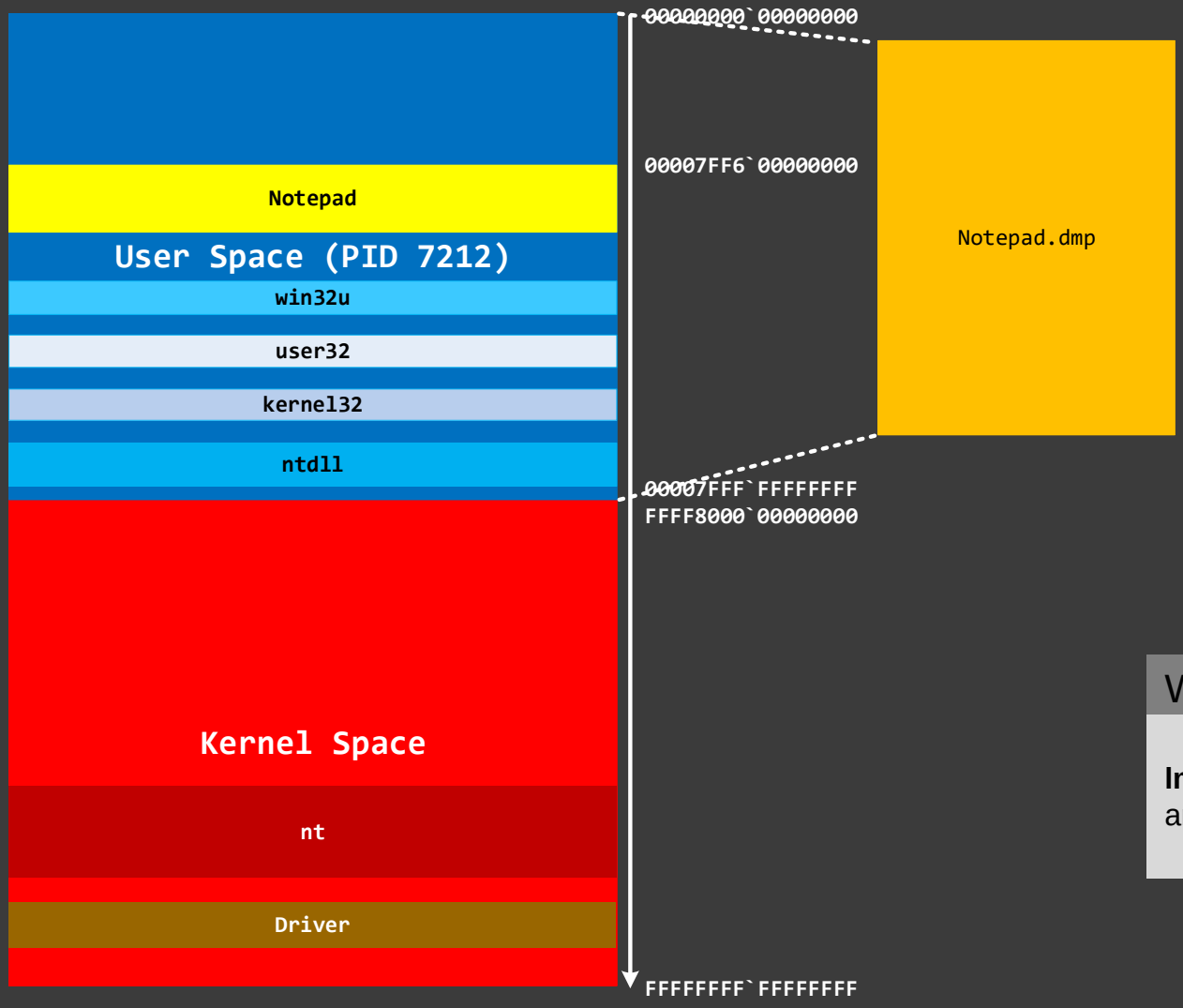
00000000

7FFFFFFF
80000000

FFFFFFFF

00000000 ... FFFFFFFF

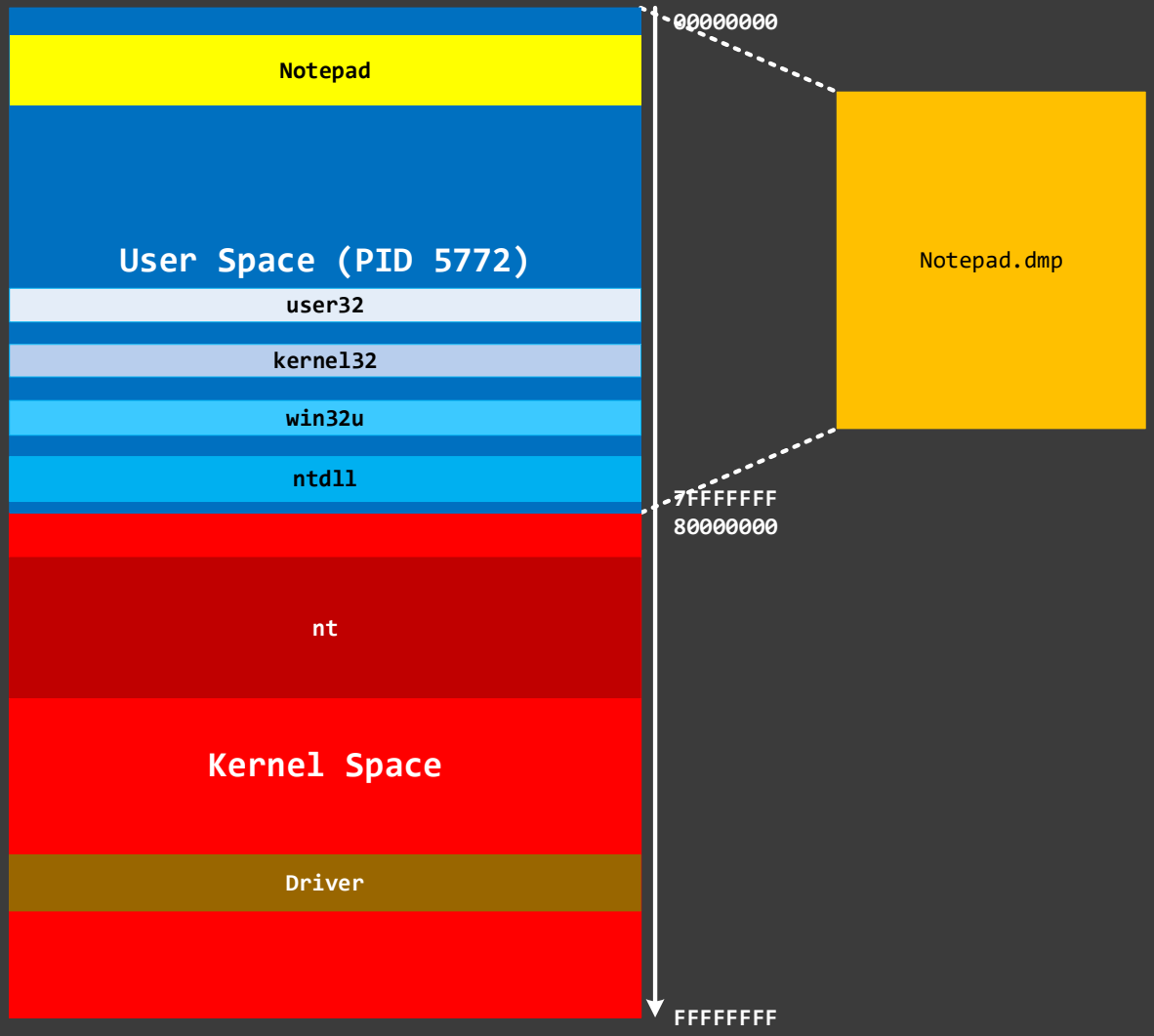
Process Memory Dump (x64)



WinDbg Commands

lmv command lists modules and their description

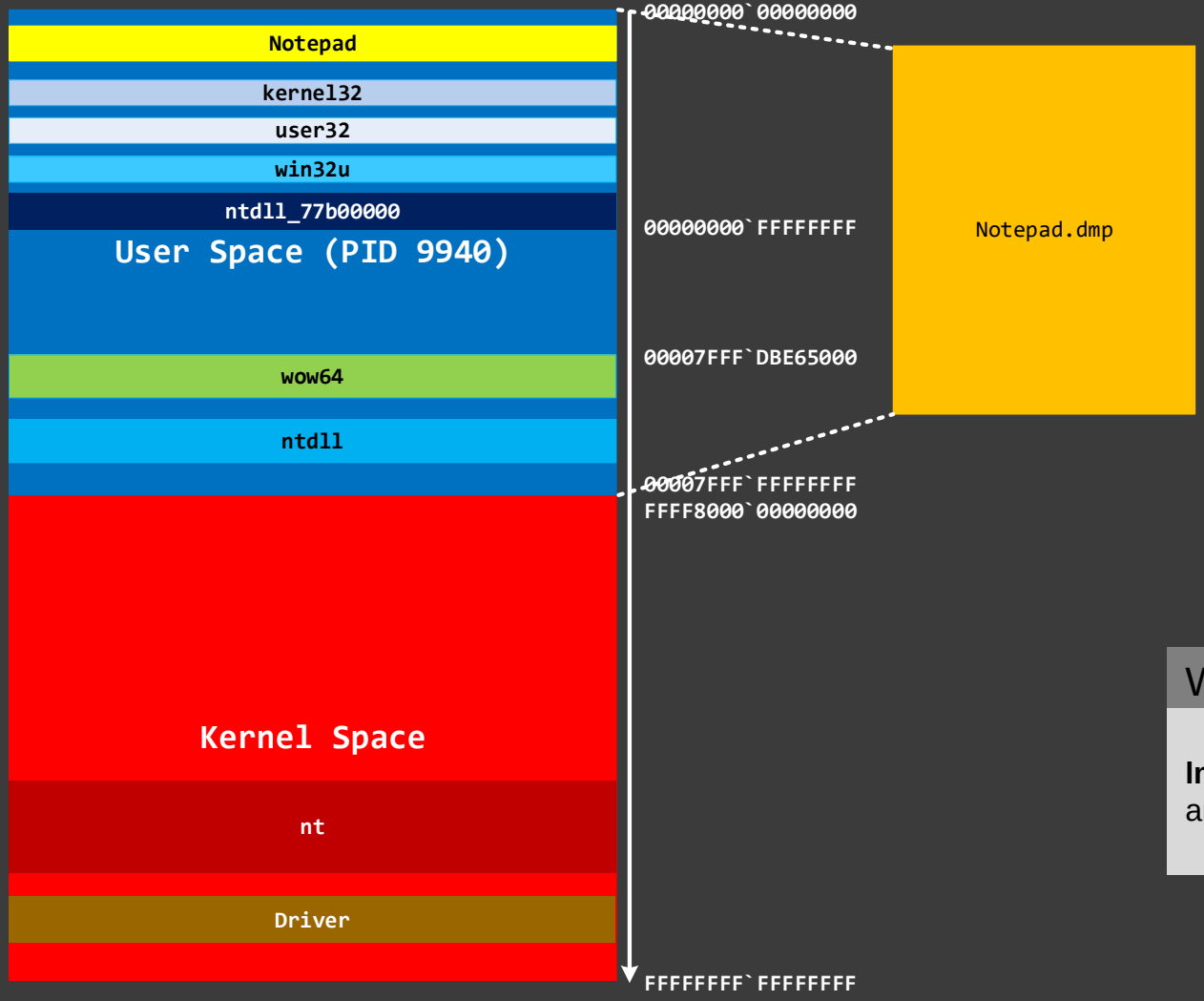
Process Memory Dump (x86)



WinDbg Commands

lmv command lists modules and their description

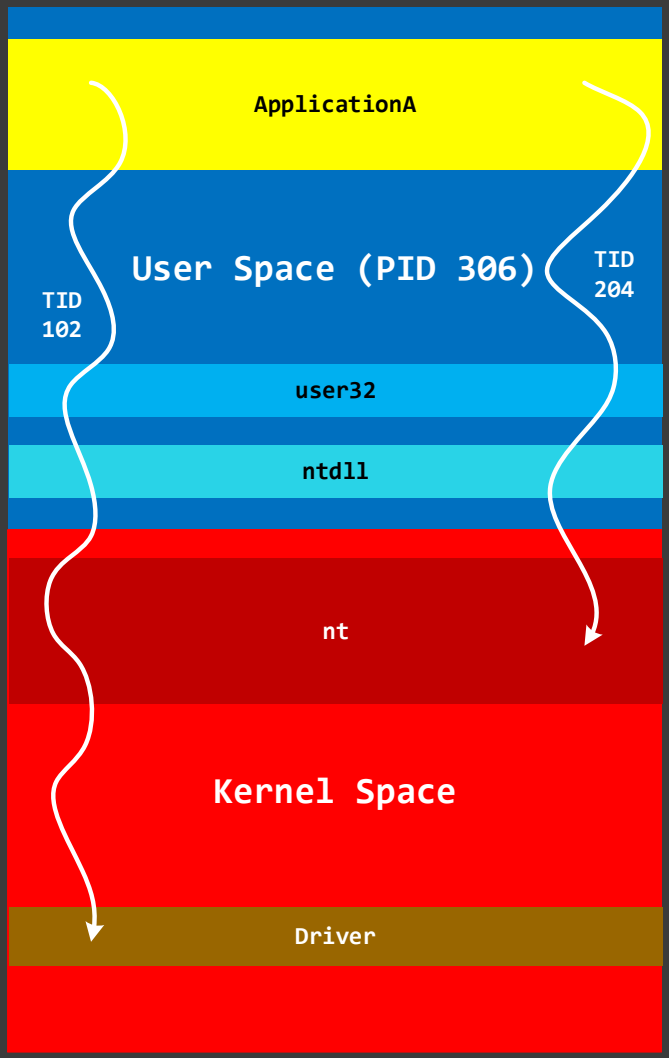
Process Memory Dump (WOW64)



WinDbg Commands

lmv command lists modules and their description

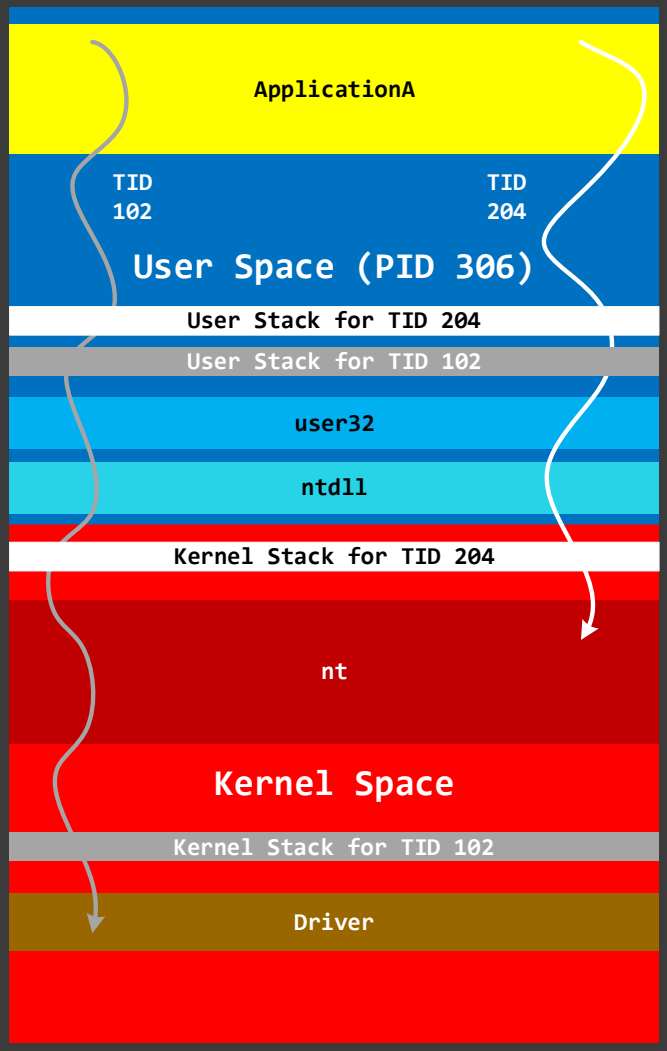
Process Threads



WinDbg Commands

Process dumps:
~<n>s switches between threads

Thread Stack Raw Data

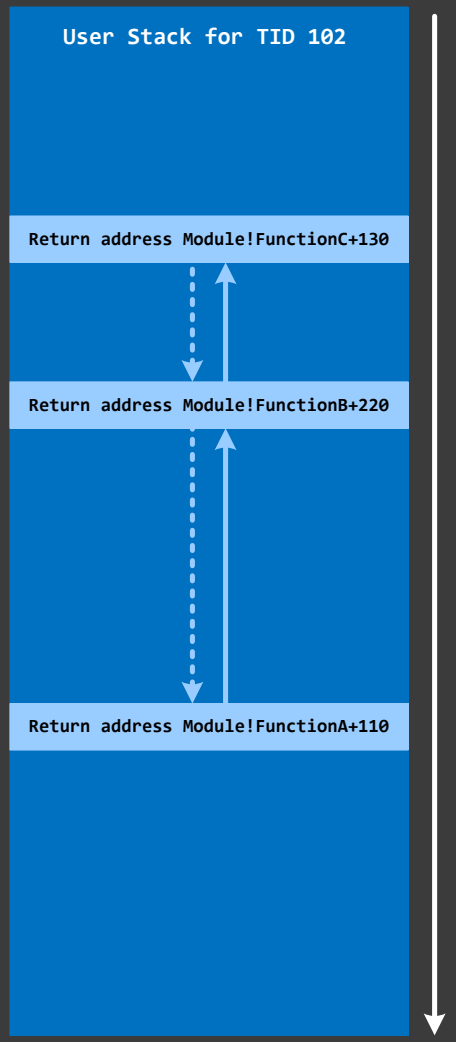


WinDbg Commands

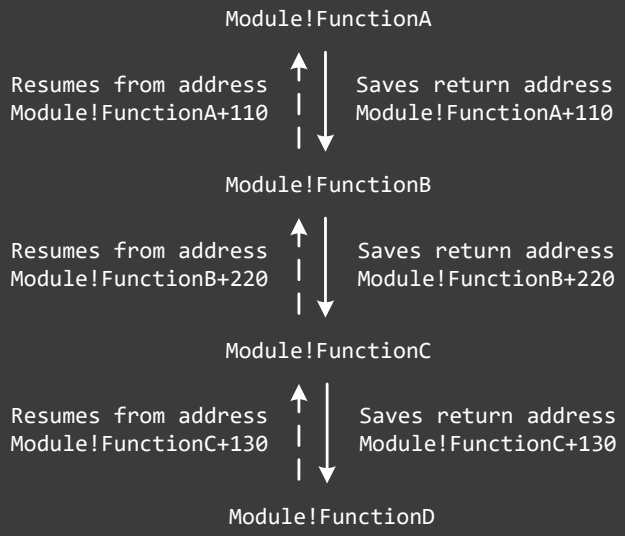
Process dumps:
!teb

Data:
dc / **dps** / **dpp** / **dpa** / **dpu**

Thread Stack Trace



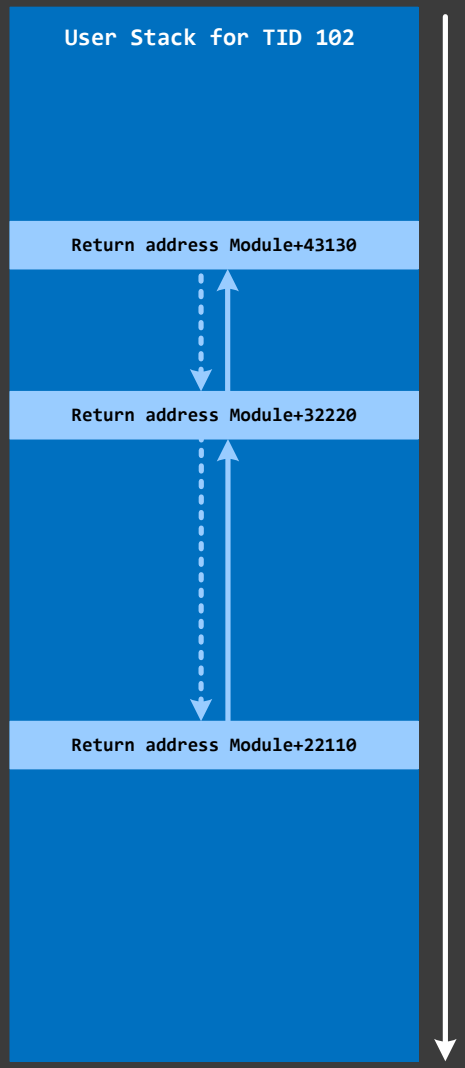

```
FunctionA()
{
  ...
  FunctionB();
  ...
}

FunctionB()
{
  ...
  FunctionC();
  ...
}

FunctionC()
{
  ...
  FunctionD();
  ...
}
```



WinDbg Commands

```
0:000> k
Module!FunctionD
Module!FunctionC+130
Module!FunctionB+220
Module!FunctionA+110
```

Thread Stack Trace (no PDB)

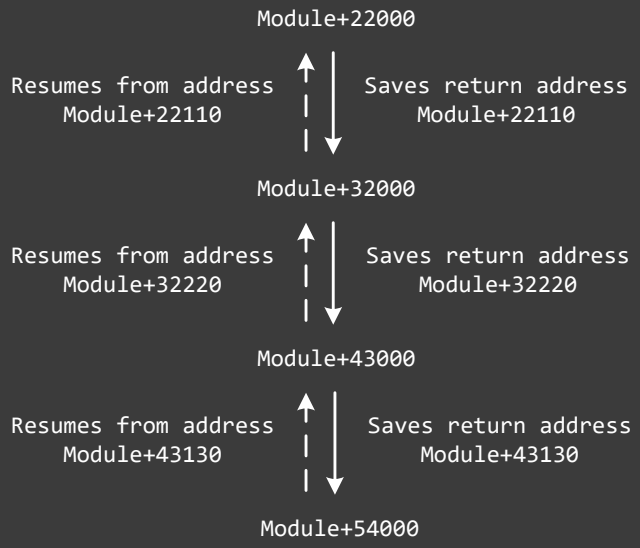



```
FunctionA()
{
  ...
  FunctionB();
  ...
}
FunctionB()
{
  ...
  FunctionC();
  ...
}
FunctionC()
{
  ...
  FunctionD();
  ...
}
```

Symbol file Module.pdb

FunctionA 22000 - 23000
FunctionB 32000 - 33000
FunctionC 43000 – 44000
FunctionD 54000 - 55000

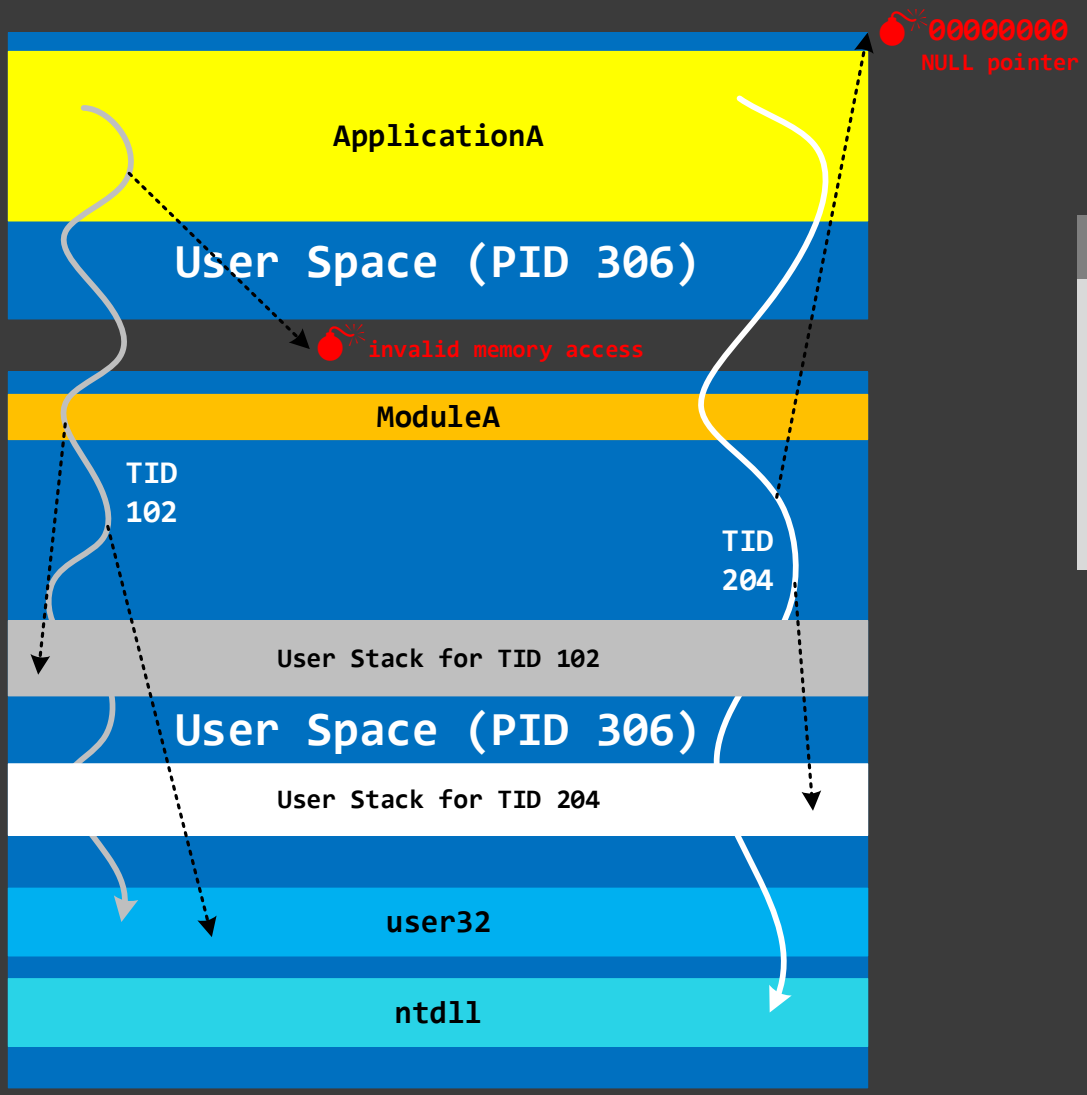
No symbols for Module



WinDbg Commands

```
0:000> k
Module+0
Module+43130
Module+32220
Module+22110
```

Exceptions (Access Violation)

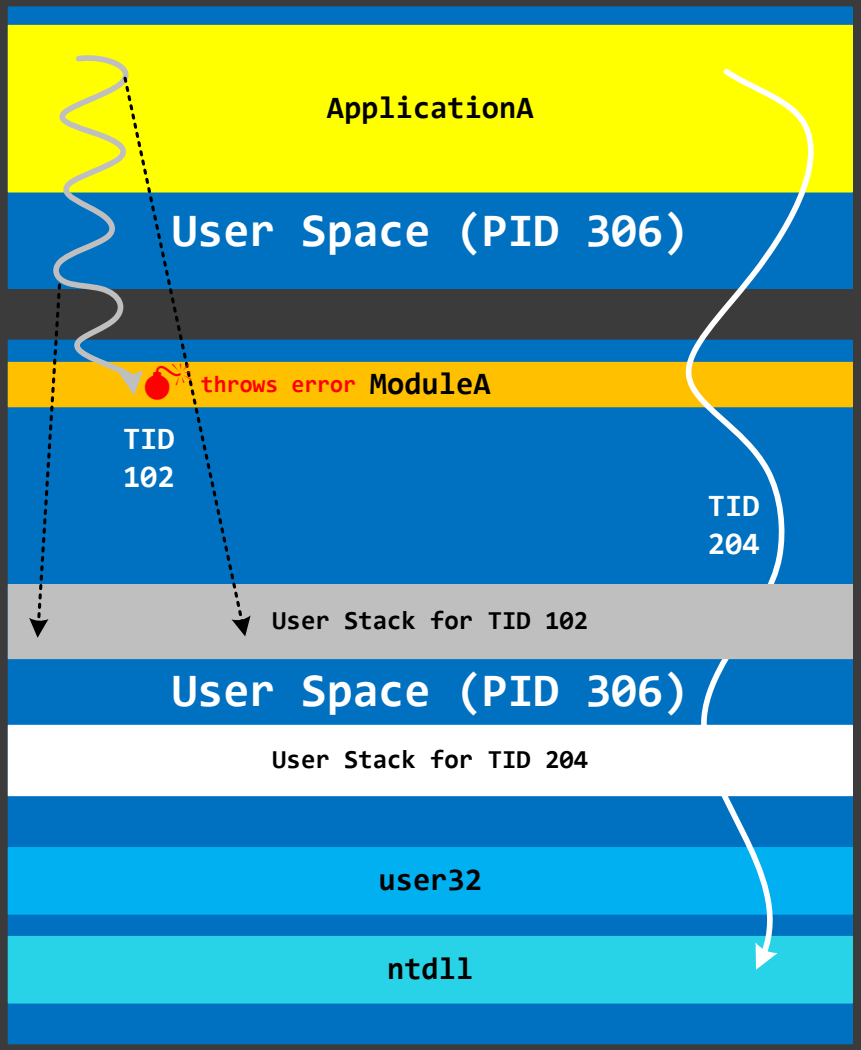


WinDbg Commands

```
address=????????
```

Set exception context (process dump):
.cxr

Exceptions (Runtime)



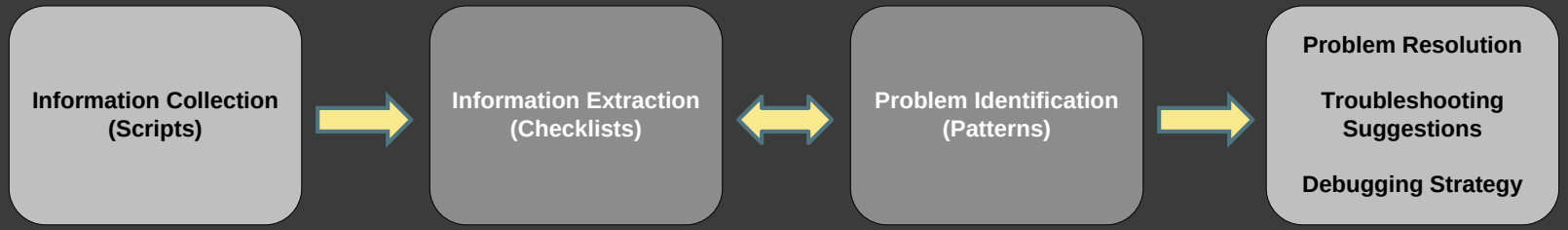
Pattern-Oriented Diagnostic Analysis

Diagnostic Pattern: a common recurrent identifiable problem together with a set of recommendations and possible solutions to apply in a specific context.

Diagnostic Problem: a set of indicators (symptoms, signs) describing a problem.

Diagnostic Analysis Pattern: a common recurrent analysis technique and method of diagnostic pattern identification in a specific context.

Diagnostics Pattern Language: common names of diagnostic and diagnostic analysis patterns. The same language for any operating system: Windows, Mac OS X, Linux, ...



Checklist: http://www.dumpanalysis.org/windows-memory-analysis-checklist

Patterns: http://www.dumpanalysis.org/blog/index.php/crash-dump-analysis-patterns/

Part 1B: Practice Exercises

Links

- Memory Dumps:

NOT IN THE PUBLIC PREVIEW VERSION

- Exercise Transcripts:

NOT IN THE PUBLIC PREVIEW VERSION

Exercise 0

- **Goal:** Install Debugging Tools for Windows and WinDbg Preview and check that symbols are setup correctly
- **Patterns:** Incorrect Stack Trace
- \AWMDA-Dumps\Exercise-0-Download-Setup-WinDbg.pdf

Process Memory Dumps

Exercises P1 – P19

Exercise P1

- **Goal:** Learn how to see dump file type and version, get a stack trace, check its correctness, perform default analysis, list threads and modules, check module version information, dump module data, check process environment

- **Patterns:** Manual Dump; Stack Trace; Not My Version; Environment Hint; Unknown Component

- \AWMDA-Dumps\Exercise-P1-Analysis-normal-process-dump-notepad-64.pdf

Exercise P2

- **Goal:** Repeat exercise P1 using 32-bit notepad process memory dump

- \AWMDA-Dumps\Exercise-P2-Analysis-normal-process-dump-notepad-32.pdf

Exercise P3

- **Goal:** Learn how to list stack traces, check their correctness, perform default analysis, list modules, check their version information, check thread age and CPU consumption
- **Patterns:** Stack Trace Collection
- \AWMDA-Dumps\Exercise-P3-Analysis-normal-process-dump-MicrosoftEdge-64.pdf

Exercise P4

- **Goal:** Learn to recognize exceptions in process memory dumps and get their context
- **Patterns:** Exception Stack Trace; Multiple Exceptions; NULL Pointer (Data)
- \AWMDA-Dumps\Exercise-P4-Analysis-process-dump-AppK-64-no-symbols.pdf

Exercise P5

- **Goal:** Learn how to load application symbols

- \AWMDA-Dumps\Exercise-P5-Analysis-process-dump-AppK-64-with-symbols.pdf

Exercise P6

- **Goal:** Learn how to recognize heap corruption, dump contents of memory, follow critical section wait chains, check error and status codes
- **Patterns:** Dynamic Memory Corruption (Process Heap); Wait Chain (Critical Sections)
- \AWMDA-Dumps\Exercise-P6-Analysis-process-dump-AppL-64.pdf

Exercise P7

- **Goal:** Learn how to debug heap corruption using page heap
- **Patterns:** Invalid Pointer; Instrumentation Information
- \AWMDA-Dumps\Exercise-P7-Analysis-process-dump-AppL2-64.pdf

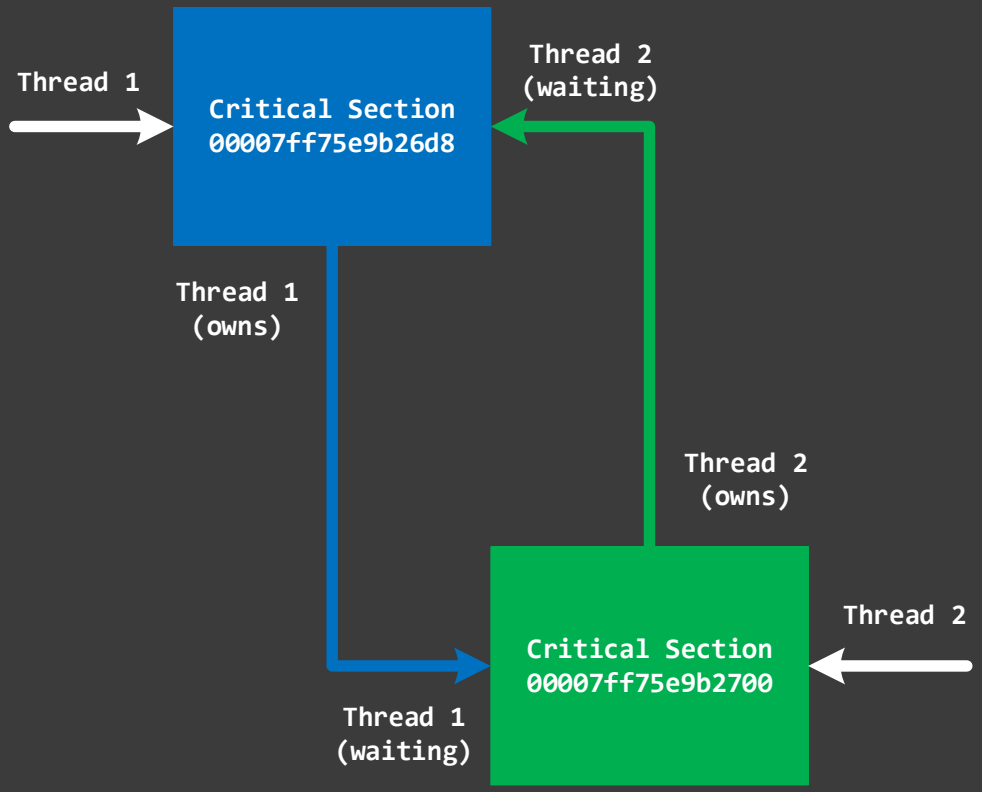
Exercise P8

- **Goal:** Learn how to recognize CPU spikes, invalid pointers, disassemble code, and reconstruct stack trace
- **Patterns:** Wild Code; Active Thread; Spiking Thread; NULL Pointer (Code); Truncated Stack Trace; Stored Exception
- \AWMDA-Dumps\Exercise-P8-Analysis-process-dump-AppM-64.pdf

Exercise P9

- **Goal:** Learn how to recognize critical section waits and deadlocks, dump raw stack data, and see hidden exceptions
- **Patterns:** Deadlock (Critical Sections); Hidden Exception
- \AWMDA-Dumps\Exercise-P9-Analysis-process-dump-AppN-64.pdf

Deadlock



Exercise P10

- **Goal:** Learn how to recognize application heap problems, buffer and stack overflow patterns, analyze raw stack data
- **Patterns:** Double Free; Local Buffer Overflow; Stack Overflow
- \AWMDA-Dumps\Exercise-P10-Analysis-process-dump-AppO-64.pdf

Exercise P11

- **Goal:** Learn how to analyze exception patterns, raw stacks, and execution residue
- **Patterns:** Divide by Zero; C++ Exception; Execution Residue
- \AWMDA-Dumps\Exercise-P11-Analysis-process-dump-AppP-64.pdf

Exercise P12

- **Goal:** Learn how to load the correct .NET WinDbg extension and analyze managed space
- **Patterns:** CLR Thread; Version-Specific Extension; JIT Code (.NET); Managed Code Exception; Managed Stack Trace
- \AWMDA-Dumps\Exercise-P12-Analysis-process-dump-AppR-32.pdf

Exercise P13

- **Goal:** Learn how to analyze 32-process saved as a 64-bit process memory dump
- **Patterns:** Virtualized Process; Message Box
- \AWMDA-Dumps\Exercise-P13-Analysis-process-dump-AppA-WOW64.pdf

Exercise P14

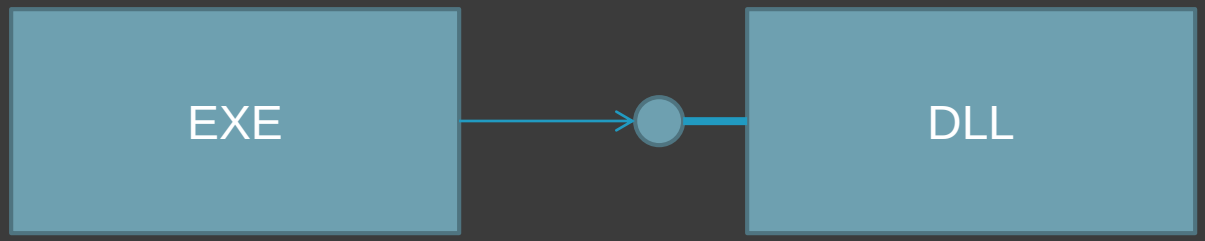
- **Goal:** Learn how to analyze process memory leaks
- **Patterns:** Thread Age; Memory Leak (Process Heap)
- \AWMDA-Dumps\Exercise-P14-Analysis-process-dump-AppS-64.pdf

Parameters and Locals

Debugging TV Frames episode 0x18

Symbol Types

- Exported and imported names



- Function and variable names

- Data types

Exercise P15

- **Goal:** Learn how to navigate function parameters in cases of reduced symbolic information in 32-bit process memory dumps
- **Patterns:** Reduced Symbolic Information
- \AWMDA-Dumps\Exercise-P15-Analysis-process-dump-notepad-32.pdf

Exercise P16

- **Goal:** Learn how to navigate function parameters in x64 process memory dumps
- **Patterns:** False Function Parameters; Injected Symbols
- \AWMDA-Dumps\Exercise-P16-Analysis-process-dump-notepad-64.pdf

Exercise P17

- **Goal:** Learn how to navigate object wait chains in 32-bit memory dumps saved with ProcDump
- **Patterns:** Embedded Comments; Wait Chain (General); No Data Types; Deadlock (Mixed Objects, User Space)
- \AWMDA-Dumps\Exercise-P17-Analysis-process-dump-AppQ-32.pdf

Exercise P18

- **Goal:** Learn how to navigate object wait chains in 64-bit memory dumps saved with ProcDump
- **Patterns:** Not My Thread; Blocked Thread (Software); Main Thread; Passive Thread (User Space); Coincidental Symbolic Information
- \AWMDA-Dumps\Exercise-P18-Analysis-process-dump-AppQ-64.pdf

Exercise P19

- **Goal:** Learn how to analyze process handle leaks
- **Patterns:** Active Space; Handle Leak
- \AWMDA-Dumps\Exercise-P19-Analysis-process-dump-AppT-64.pdf

Pattern Links

Spiking Thread
C++ Exception
Divide by Zero
Dynamic Memory Corruption (Process Heap)
Execution Residue
Invalid Pointer
Manual Dump
Managed Stack Trace
Not My Version
NULL Pointer (Code)
Stack Trace Collection
Environment Hint
Unknown Component
Virtualized Process
Version-Specific Extension
False Function Parameters
Reduced Symbolic Information
Stored Exception
Instrumentation Information
JIT Code (.NET)
Embedded Comment
Deadlock (Mixed Object, User Space)
Blocked Thread (Software)
Passive Thread (User Space)
Active Space

CLR Thread
Deadlock (Critical Sections)
Double Free
Exception Stack Trace
Hidden Exception
Local Buffer Overflow
Managed Code Exception
Multiple Exceptions
NULL Pointer (Data)
Stack Trace
Stack Overflow
Wild Code
Wait Chain (Critical Sections)
Message Box
Memory Leak (Process Heap)
Injected Symbols
Truncated Stack Trace
Incorrect Stack Trace
Active Thread
Thread Age
Wait Chain (General)
Not My Thread
Main Thread
Coincidental Symbolic Information
Handle Leak

Pattern Classification

Space/Mode
Hooksware
DLL Link Patterns
Contention Patterns
Stack Trace Patterns
Exception Patterns
Module Patterns
Thread Patterns
Dynamic Memory Corruption Patterns
.NET / CLR / Managed Space Patterns
Falsity and Coincidence Patterns

Memory dump type
Wait Chain Patterns
Insufficient Memory Patterns
Stack Overflow Patterns
Symbol Patterns
Meta-Memory Dump Patterns
Optimization Patterns
Process Patterns
Deadlock and Livelock Patterns
Executive Resource Patterns
RPC, LPC and ALPC Patterns

Pattern Case Studies

More than 70 multiple pattern case studies:

http://www.dumpanalysis.org/blog/index.php/pattern-cooperation/

Pattern Interaction chapters in
Memory Dump Analysis Anthology

Additional Resources

- WinDbg Help / WinDbg.org (quick links)
- DumpAnalysis.org / SoftwareDiagnostics.Institute / PatternDiagnostics.com
- Debugging.TV / YouTube.com/DebuggingTV / YouTube.com/PatternDiagnostics
- Windows Internals, 6th ed., 7th ed.
- Advanced Windows Debugging
- Inside Windows Debugging
- Principles of Memory Dump Analysis
- Windows Debugging Notebook: Essential User Space WinDbg Commands
- Encyclopedia of Crash Dump Analysis Patterns, 2nd edition
- Memory Dump Analysis Anthology

Further Training Courses

- Practical Foundations of Windows Debugging, Disassembling, Reversing
- Advanced Windows Memory Dump Analysis with Data Structures, 3rd edition
- Accelerated .NET Memory Dump Analysis, 3rd edition
- Accelerated Windows Malware Analysis with Memory Dumps, 2nd edition
- Accelerated Disassembly, Reconstruction and Reversing
- Accelerated Windows Debugging3, 2nd edition

Q&A

Please send your feedback using the contact form on PatternDiagnostics.com

Thank you for attendance!