Bypassing LSA Protection (a.k.a. RunAsPPL) in Userland

> Abusing the `DefineDosDevice` API actually has a second use, it's an Administrator to Protected Process Light (PPL) bypass. - *James Forshaw* (2018)

Who am I?

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We all know LSA Protection, or do we?

What I *knew* back then.

- Configure **a simple registry key** and reboot, that's it!
- From now on, other processes (Mimikatz, procdump, …) **can't access LSASS**
- …unless you go from Ring 3 to Ring 0, a.k.a. the Kernel, using **a custom driver**.

How/why does it work?

- *Binaries that are not signed can't open LSASS?*
- … 🤔 Well, let's do some research…

How to enable LSA Protection

Configure the `RunAsPPL` value in the registry and reboot

- `HKLM\SYSTEM\CurrentControlSet\Control\Lsa` -> `RunAsPPL = 0x00000001`

Remarks / Limitations

ℹ️ Only available starting from **Windows 8.1 / Server 2012 R2**

⚠️ If **Secure Boot** is enabled, the setting is persistent (stored in the UEFI firmware)!

⚠️ **Prevents non-signed** plug-ins and drivers (**smart card readers**, **password filters**, etc.) from being loaded in LSASS.

Source: *https://docs.microsoft.com/en-us/windows-server/security/credentials-protection-and-management/configuring-additional-lsa-protection*

How good is this LSA Protection?

LSA Protection against Mimikatz - Round 1

```
mimikatz # privilege::debug
Privilege '20' OK

mimikatz # sekurlsa::logonPasswords
ERROR kuhl_m_sekurlsa_acquireLSA ; Handle on memory (0x00000005)
```

✅ The current user is an administrator

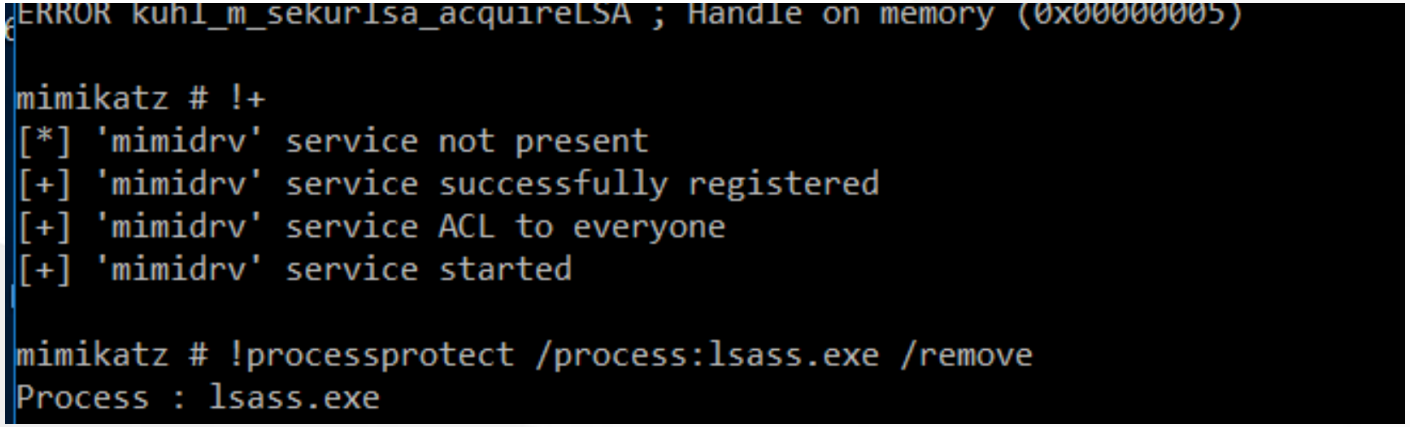
✅ The current user has `SeDebugPrivilege`

❌ `0x00000005` = "**Access is denied**"

`OpenProcess` failed, **the Kernel refused** to return a process handle to the caller.

How good is this LSA Protection?

LSA Protection against Mimikatz - Round 2



ℹ️ Mimikatz is shipped with **a signed driver**: `mimidrv.sys` (load it with `!+`)

✅ Use the command `!processprotect /process:lsass.exe /remove`

ℹ️ This **drops the protection flag** of the Process object in the Kernel memory

⚠️ Easily flagged by AV/EDR

Protected Processes (Light)

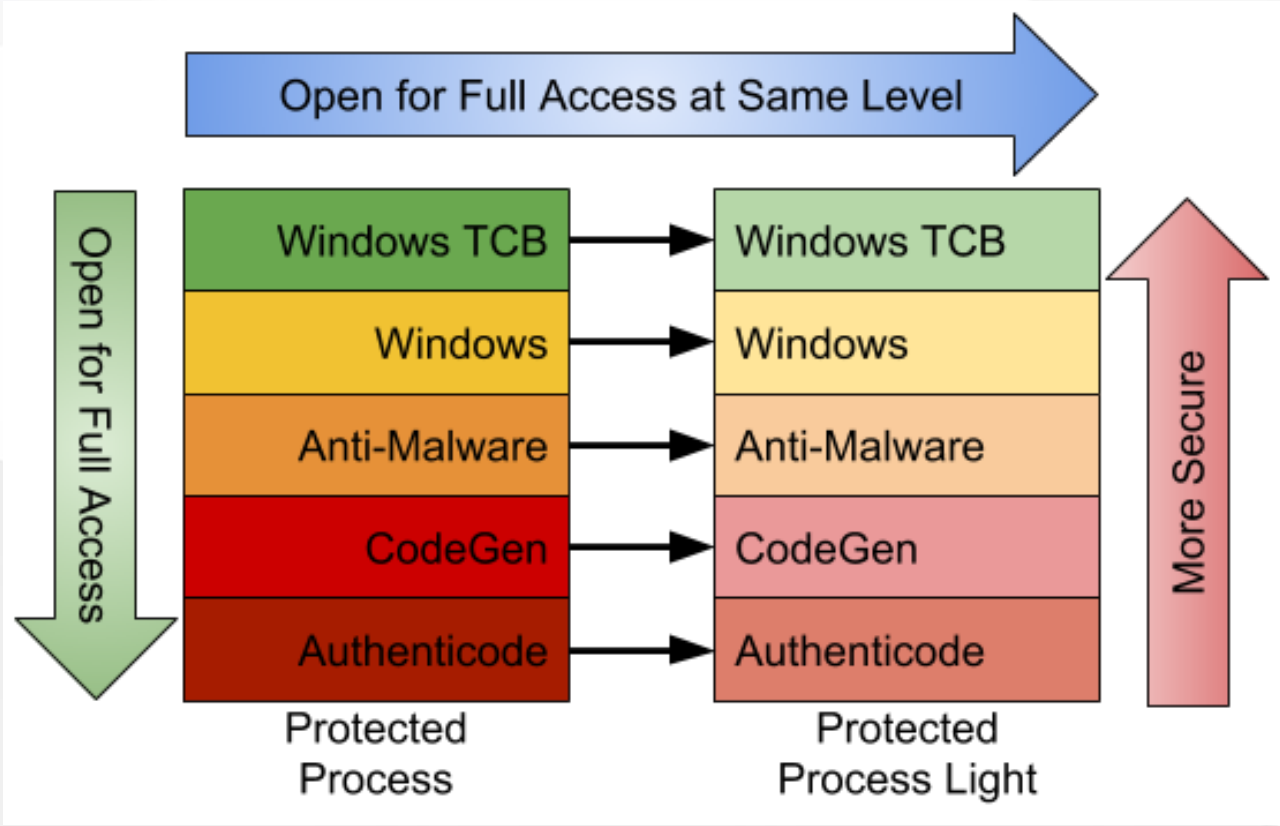
Protected Processes (PP)

- Introduced with **Windows Vista / Server 2008**
- Objective: protect media content and comply with **Digital Rights Management**!
- The image file had to be signed with a special **Windows Media Certificate**

Protected Processes Light (PPL)

- Introduced with **Windows 8.1 / Server 2012 R2**
- A **protection level** is added (signer type)
    - => **Some processes are more protected than others**

Protection levels & Signer types



Source: *https://googleprojectzero.blogspot.com/2018/10/injecting-code-into-windows-protected.html*

A few examples

Windows Defender - `MsMpEng.exe`

Process	CPU	Private Bytes	Working Set	PID	Description	Company Name	Protection
MsMpEng.exe	0.03	499,324 K	152,952 K	5312	Antimalware Service Execut...	Microsoft Corporation	PsProtectedSignerAntimalware-Light

LSASS when **RunAsPPL** is enabled - `lsass.exe`

Process	CPU	Private Bytes	Working Set	PID	Description	Company Name	Protection
lsass.exe	0.01	9,992 K	9,956 K	732	Local Security Authority Proc...	Microsoft Corporation	PsProtectedSignerLsa-Light

A critical process - `wininit.exe`

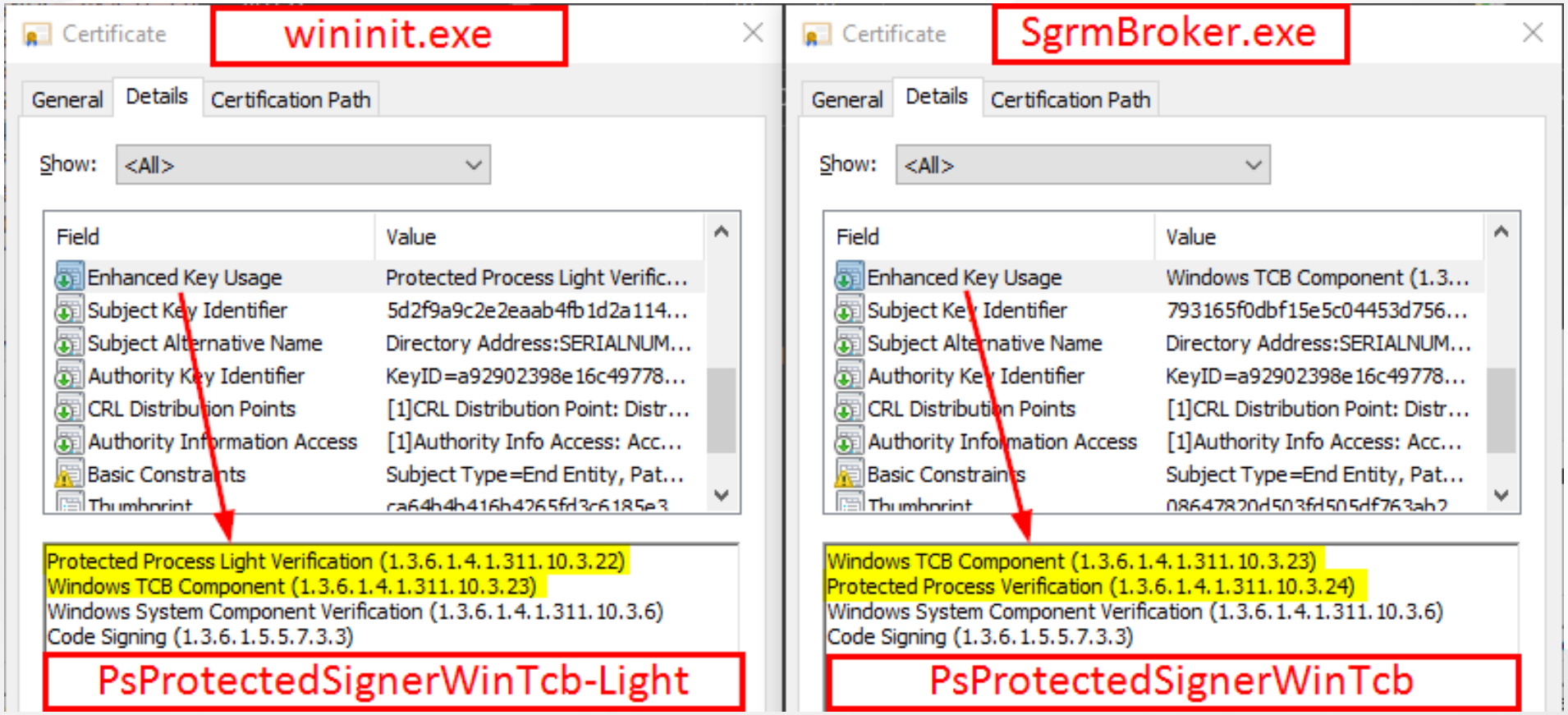
Process	CPU	Private Bytes	Working Set	PID	Description	Company Name	Protection
wininit.exe		1,700 K	384 K	1004	Windows Start-Up Application	Microsoft Corporation	PsProtectedSignerWinTcb-Light

SgrmBroker - `SgrmBroker.exe`

Process	CPU	Private Bytes	Working Set	PID	Description	Company Name	Protection
SgrmBroker.exe		5,900 K	4,756 K	10644	System Guard Runtime Monit...	Microsoft Corporation	PsProtectedSignerWinTcb

How is the protection level determined?

The image file's certificate contains a special "**EKU**" field.



Protected Processes in a nutshell

ℹ️ **Protection level**: Protected Process (PP) or Protected Process Light (PPL)
ℹ️ **Signer type**: WinTCB > Windows > Lsa > AntiMalware > Authenticode
ℹ️ **LSA Protection**: if `RunAsPPL=1` => LSASS runs as a **PPL** with the signer type **Lsa**

Here are the basic rules:

❌ A **"standard" process** *cannot open a **PP(L)***
⚠️ A **PP(L)** can open a another **PP(L)** only if its protection level is **greater or equal**
ℹ️ A **PP(L)** can be created by any user as long as the **image file is signed by MS** and its certificate contains the appropriate **EKU** values.

✅ If I'm able to **run arbitrary code inside a PPL with WinTCB level**, I can open any PPL.

How do PPs and PPLs handle DLL loading?

The EXE must be **digitally signed by Microsoft** ➡️ "impossible" to run arbitrary code.

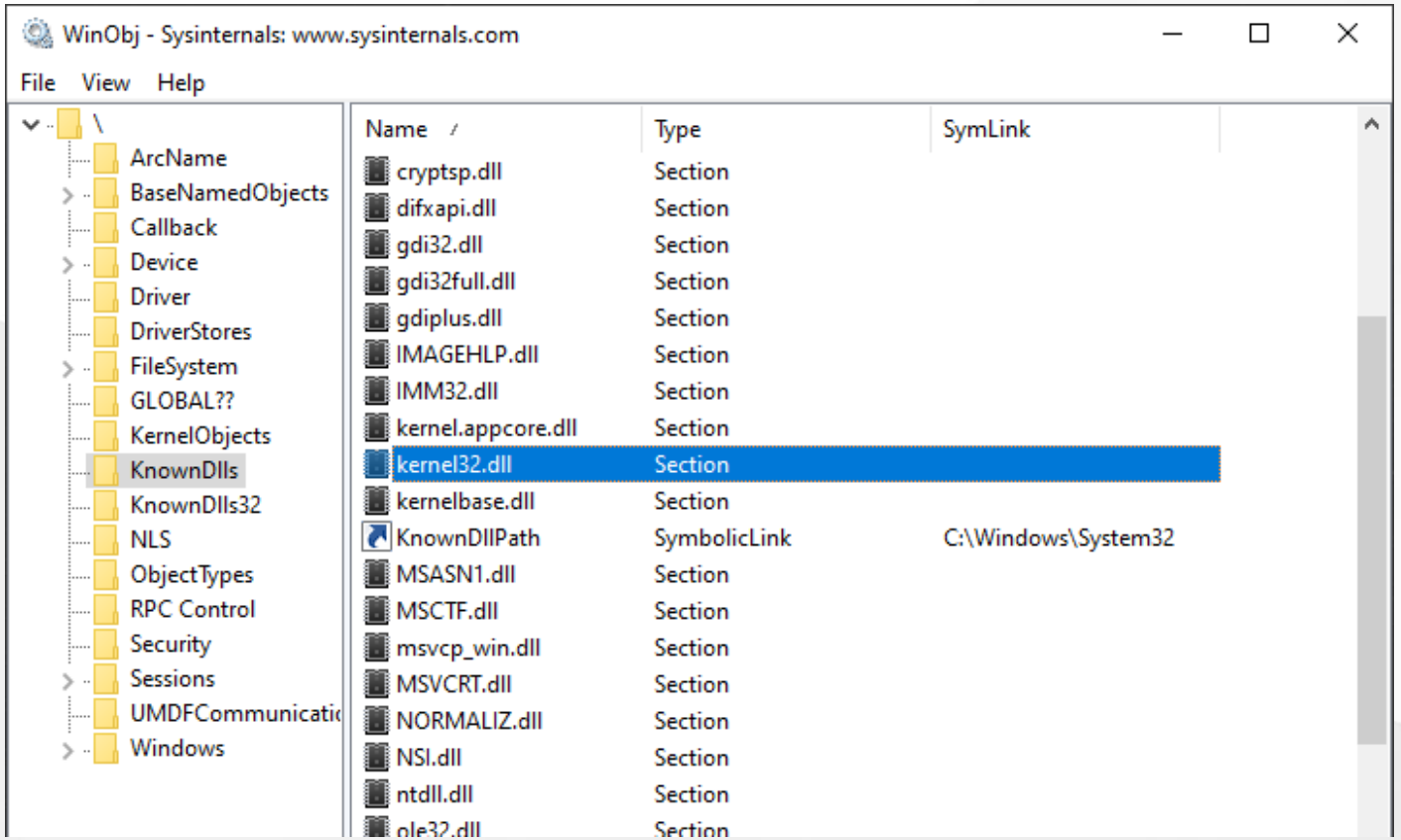
... but what about **imported DLLs**? They must be signed as well but...

DLL search order reminder:

1. DLLs already loaded in memory
2. **Known DLLs** 🔍
3. Application's directory
4. System directories (`C:\Windows\System32\` , `C:\Windows\System\` , ...)
5. Current directory
6. `%PATH%` directories

Known DLLs

Known DLLs are Section objects that are stored in the **Object directory** `\KnownDlls`



Known DLLs: PP vs PPL

Protected Process (PP)

✅ Known Dlls are loaded from the disk. ➡️ The digital signature is **always verified**.

Time ...	Process Name	PID	User	Operation	Path
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	CreateFile	C:\Windows\System32\kernel32.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	QueryBasicInformationFile	C:\Windows\System32\kernel32.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	CloseFile	C:\Windows\System32\kernel32.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	CreateFile	C:\Windows\System32\kernel32.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	CreateFileMapping	C:\Windows\System32\kernel32.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	QueryStandardInformationFile	C:\Windows\System32\kernel32.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	CreateFileMapping	C:\Windows\System32\kernel32.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	QueryStandardInformationFile	C:\Windows\System32\kernel32.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	CreateFileMapping	C:\Windows\System32\kernel32.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	CreateFileMapping	C:\Windows\System32\kernel32.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	CloseFile	C:\Windows\System32\kernel32.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	CreateFile	C:\Windows\System32\KernelBase.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	QueryBasicInformationFile	C:\Windows\System32\KernelBase.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	CloseFile	C:\Windows\System32\KernelBase.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	CreateFile	C:\Windows\System32\KernelBase.dll
4:23:2...	SgmBroker.exe	5948	DESKTOP-VB8CQ73\lab-user	CreateFileMapping	C:\Windows\System32\KernelBase.dll

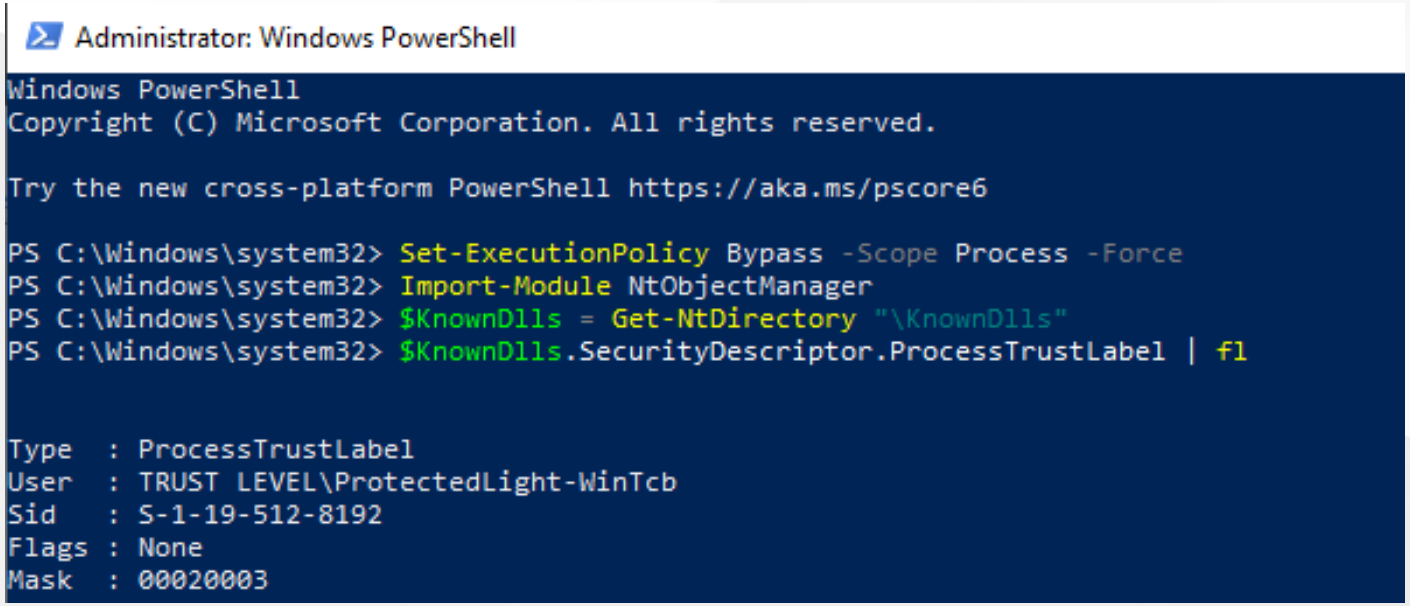
Protected Process Light (PPL)

⚠️ Known DLLs are loaded from the existing Sections. ➡️ **No signature validation!** 💣

Create your own Known DLL entry!

As an administrator, create a new Section object in `\KnownDlls` and map your own image file ➡️ DLL hijacking for the win! 😎

Hmm... It's not that simple! 😔 The `\KnownDlls` directory and the `KnownDlls` registry key are protected with a "**Process Trust Label**".



Introducing the DefineDosDevice API

> Abusing the `DefineDosDevice` API actually has a second use, it's an Administrator to Protected Process Light (PPL) bypass. - *James Forshaw* (2018)

Source: *https://googleprojectzero.blogspot.com/2018/08/windows-exploitation-tricks-exploiting.html*

```
BOOL DefineDosDeviceW(DWORD dwFlags, LPCWSTR lpDeviceName, LPCWSTR lpTargetPath);
```

ℹ️ Examples: plug a **USB key**, map a **network share**, etc.

```
DefineDosDeviceW(dwFlags, L"E:", "\\Device\\HarddiskVolume5");
```

ℹ️ `DefineDosDevice` is a wrapper for an RPC function exposed by the **CSRSS service**.

✅ The **CSRSS service** is executed as a **PPL** with the signer type **WinTCB**!

A TOCTOU vulnerability in DefineDosDevice

```
DWORD dwFlags = DDD_NO_BROADCAST_SYSTEM | DDD_RAW_TARGET_PATH;
DefineDosDeviceW(dwFlags, L"DEVICE_NAME", L"TARGET_PATH");
```

1. **Impersonate the client**, try to open `\??\DEVICE_NAME` and ***revert to self***.
2. If it exists, determine whether it's **global** (i.e. object path start with `\GLOBAL??\` ?).
3. 💣 If so, **disable impersonation**. 💣 (i.e. exec as `SYSTEM` + PPL/WinTCB)
4. If the symbolic link (step 1) exists, delete it.
5. (If impersonation is **enabled**, ~~**impersonate the client again**~~.)
6. **Create the symbolic link** `\??\DEVICE_NAME` -> `TARGET_PATH` .
7. (If impersonation is **enabled**, ~~***revert to self***~~.)
8. Mark the new symbolic link object as "**Permanent**".

A TOCTOU vulnerability in DefineDosDevice

Two operations:

- **Step 1/2:** a **check** is done **in the context of the RPC client**.
- **Step 6:** the symbolic link **could** be created **in the context of the service**.

The same path in both cases **but** `\??\DEVICE_NAME` **= ...**

- `\GLOBAL??\DEVICE_NAME` for **SYSTEM**
- `\Sessions\0\DosDevices\00000000-XXXXXXXX\DEVICE_NAME` for **any other user**

We need to find a value for `DEVICE_NAME` such that `\??\DEVICE_NAME` resolves to: **...**

- A **global** object (`\GLOBAL??\...`) when the caller is **impersonated**.
- `\KnownDlls\foo.dll` when interpreted as **SYSTEM**

The exploit

We can exploit this **TOCTOU** using a path such as `GLOBALROOT\KnownDlls\foo.dll`.

1 The service will open `\??\GLOBALROOT\KnownDlls\foo.dll` **as the RPC client**.

```
\??\GLOBALROOT\KnownDlls\foo.dll = \Sessions\0\DosDevices\00000000-XXXXXXXX\GLOBALROOT\KnownDlls\foo.dll
-> \GLOBAL??\KnownDlls\FOO.dll
```

2 This object does not exist but we can create it, and its path starts with `\GLOBAL??\`.

3 The object is considered as "**global**" so **impersonation is disabled**.

6 **Create the symlink as SYSTEM** `\??\GLOBALROOT\KnownDlls\foo.dll`.

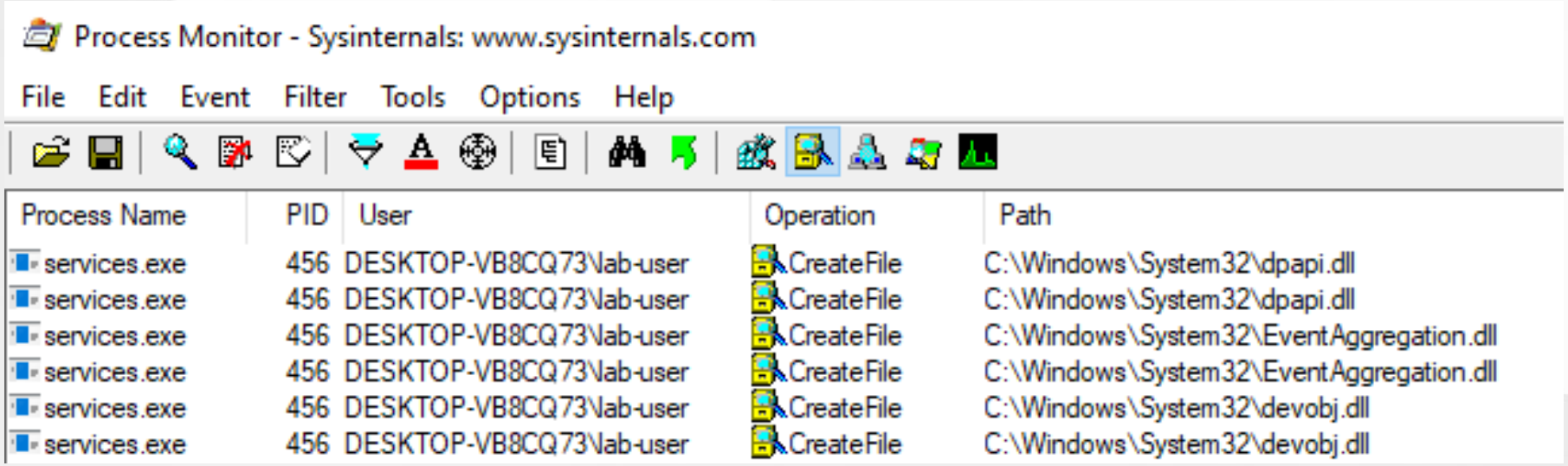
```
\??\GLOBALROOT\KnownDlls\foo.dll = \GLOBAL??\GLOBALROOT\KnownDlls\FOO.dll
-> \KnownDlls\FOO.dll
```

🏆 Enjoy your new symbolic link `\KnownDlls\foo.dll`!

Running arbitrary code inside a PPL

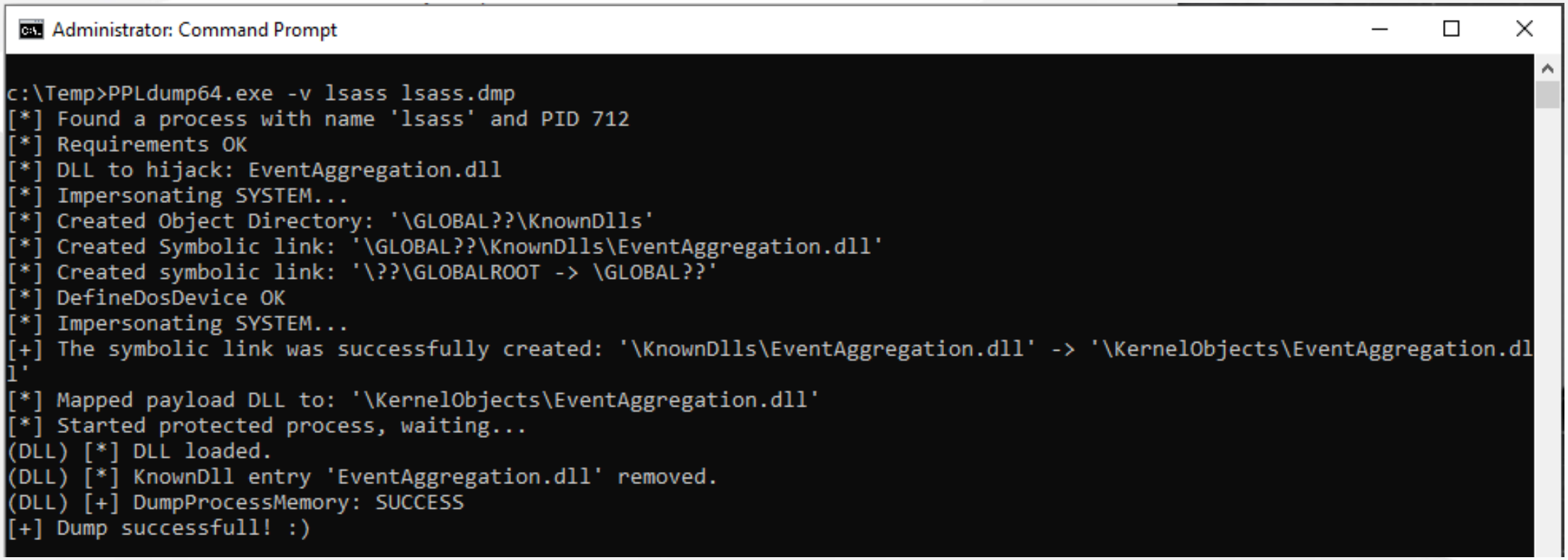
Objective - Hijack a DLL of an EXE we can execute as a PPL with the level `WinTCB`.

- Only 4 built-in executables match this criteria.
- The best candidate is by far **`services.exe`** (SCM).
- It loads several DLLs which are not Known DLLs (depends on the OS version).



PPLdump

https://github.com/itm4n/PPLdump



References

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- https://blog.scrt.ch/2021/04/22/bypassing-lsa-protection-in-userland/
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