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Lessons From the Field:
Vulnerabilities in Credentials & How to Fix Them

Paula Januszkiewicz

CQURE: CEO, Cybersecurity Expert
CQURE Academy: Trainer
MVP: Enterprise Security, MCT
Microsoft Regional Director
www.cqureacademy.com
paula@cqure.us

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CQURE INC.
Paula Januszkiewicz is a CEO and Found
also an Enterprise Security MVP and a wo
Customers all around the world. She has
deep belief that positive thinking is key
extreme attention to details and confere

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2011
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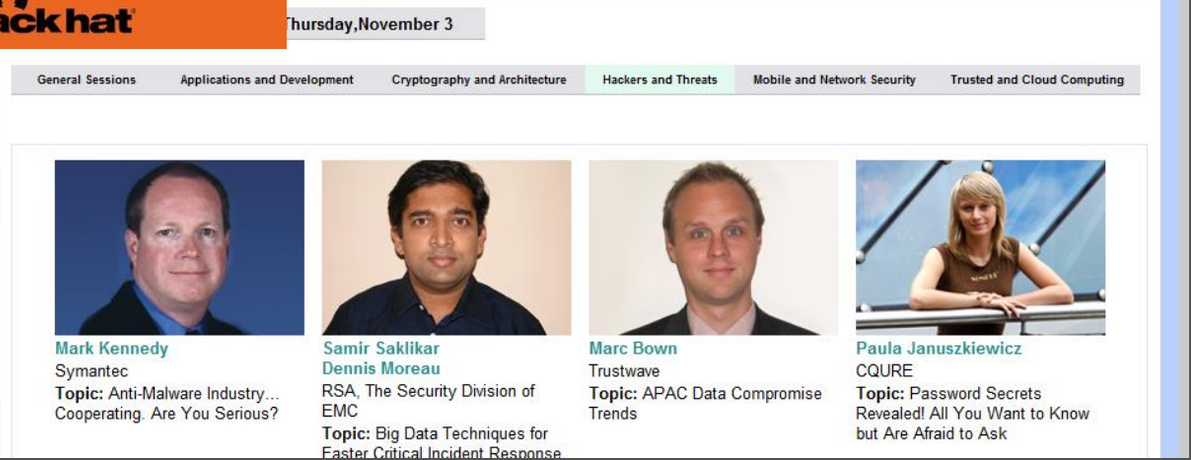
Thursday,November 3
General Sessions
Applications and Development
Cryptography and Architecture
Hackers and Threats
Mobile and Network Security
Trusted and Cloud Computing
Mark Kennedy
Symantec
Topic: Anti-Malware Industry... Cooperating. Are You Serious?
Samir Saklikar
Dennis Moreau
RSA, The Security Division of EMC
Topic: Big Data Techniques for
Marc Bown
Trustwave
Topic: APAC Data Compromise Trends
Paula Januszkiewicz
CQURE
Topic: Password Secrets Revealed! All You Want to Know but Are Afraid to Ask

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Websites
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+ configuration reviews

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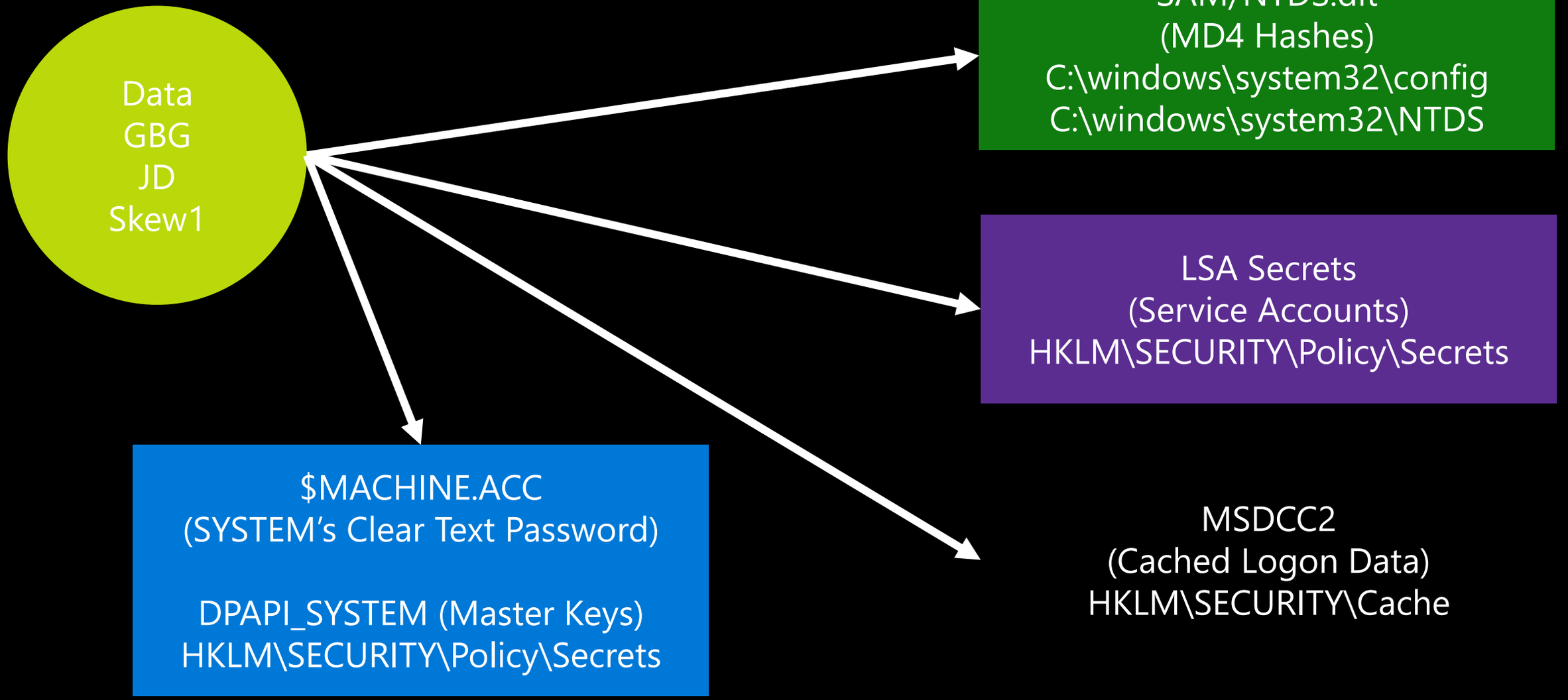
SAMSUNG
Solid State Drive

Definition of credentials

Set of data
that allows other party
to believe me
when I tell who I am

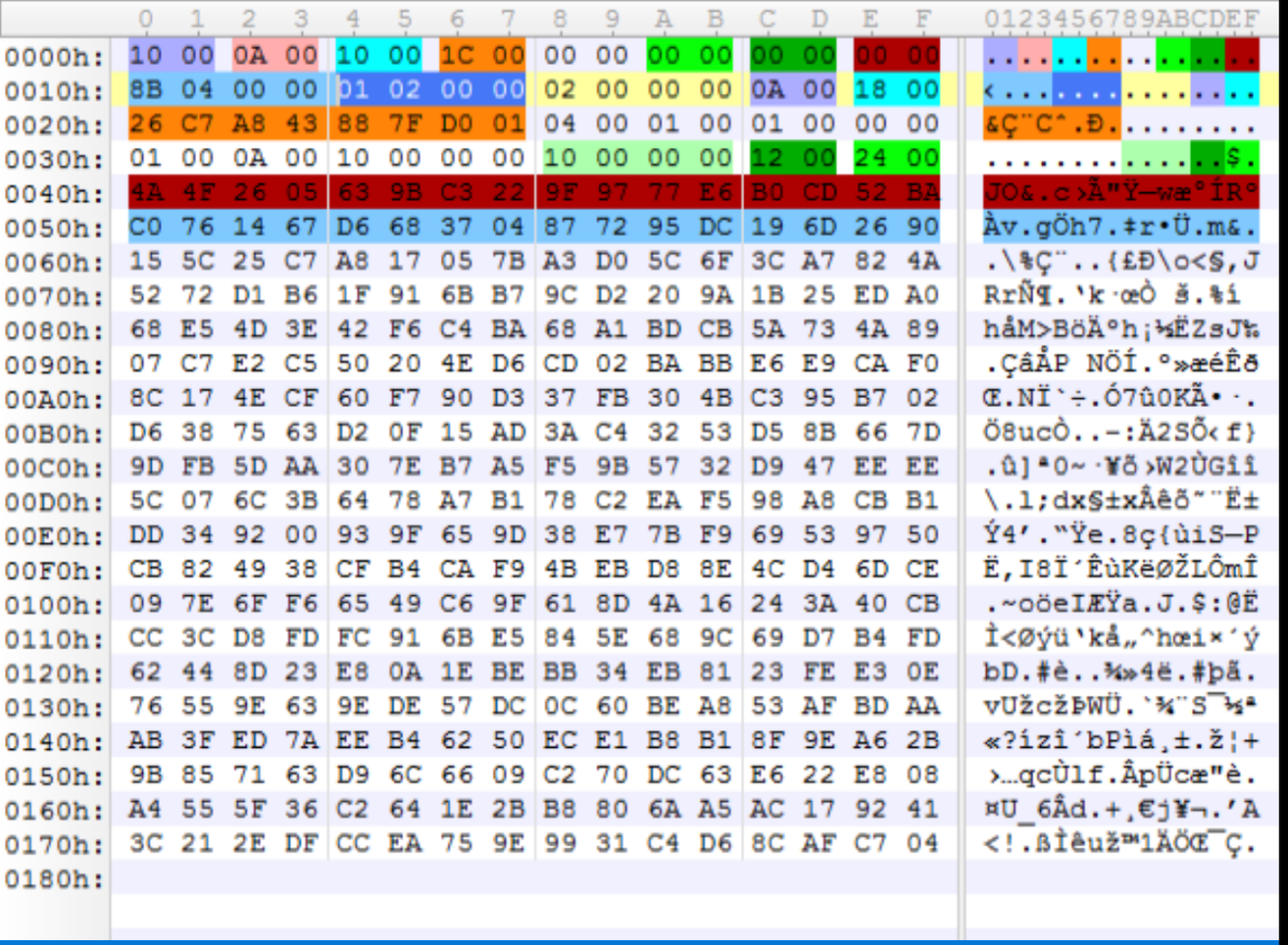
Bootkey:

Class names for keys from HKLM\SYSTEM\CCS\Control\Lsa



More information: http://cqureacademy.com/blog

Are ‘cached credentials’ safe?



	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	0123456789ABCDEF
0000h:	10	00	0A	00	10	00	1C	00	00	00	00	00	00	00	00	00	.....
0010h:	8B	04	00	00	01	02	00	00	02	00	00	00	0A	00	18	00	‹.....
0020h:	26	C7	A8	43	88	7F	D0	01	04	00	01	00	01	00	00	00	&Ç¨C^.Ð.....
0030h:	01	00	0A	00	10	00	00	00	10	00	00	00	12	00	24	00	.....$.
0040h:	4A	4F	26	05	63	9B	C3	22	9F	97	77	E6	B0	CD	52	BA	JO&.c›Ã"Ÿ—wæ°ÍR°
0050h:	C0	76	14	67	D6	68	37	04	87	72	95	DC	19	6D	26	90	Àv.gÖh7.‡r•Ü.m&.
0060h:	15	5C	25	C7	A8	17	05	7B	A3	D0	5C	6F	3C	A7	82	4A	.\%Ç¨..{£Ð\o<§,J
0070h:	52	72	D1	B6	1F	91	6B	B7	9C	D2	20	9A	1B	25	ED	A0	RrÑ¶.'k·œÒ š.%í
0080h:	68	E5	4D	3E	42	F6	C4	BA	68	A1	BD	CB	5A	73	4A	89	håM>BöÄºh¡½ËZsJ‰
0090h:	07	C7	E2	C5	50	20	4E	D6	CD	02	BA	BB	E6	E9	CA	F0	.ÇâÅP NÖÍ.º»æéÊð
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00B0h:	D6	38	75	63	D2	0F	15	AD	3A	C4	32	53	D5	8B	66	7D	Ö8ucÒ..-:Ä2SÕ‹f}
00C0h:	9D	FB	5D	AA	30	7E	B7	A5	F5	9B	57	32	D9	47	EE	EE	.û]ª0~·¥õ›W2ÙGîî
00D0h:	5C	07	6C	3B	64	78	A7	B1	78	C2	EA	F5	98	A8	CB	B1	\.l;dx§±xÂêõ˜¨Ë±
00E0h:	DD	34	92	00	93	9F	65	9D	38	E7	7B	F9	69	53	97	50	Ý4'.“Ÿe.8ç{ùiS—P
00F0h:	CB	82	49	38	CF	B4	CA	F9	4B	EB	D8	8E	4C	D4	6D	CE	Ë‚I8Ï´ÊùKëØŽLÔmÎ
0100h:	09	7E	6F	F6	65	49	C6	9F	61	8D	4A	16	24	3A	40	CB	.~oöeIÆŸa.J.$:@Ë
0110h:	CC	3C	D8	FD	FC	91	6B	E5	84	5E	68	9C	69	D7	B4	FD	Ì<Øýü'kå„^hœi×´ý
0120h:	62	44	8D	23	E8	0A	1E	BE	BB	34	EB	81	23	FE	E3	0E	bD.#è..¾»4ë.#þã.
0130h:	76	55	9E	63	9E	DE	57	DC	0C	60	BE	A8	53	AF	BD	AA	vUžcžÞWÜ.`¾¨S¯½ª
0140h:	AB	3F	ED	7A	EE	B4	62	50	EC	E1	B8	B1	8F	9E	A6	2B	«?ízî´bPìá¸±.ž¦+
0150h:	9B	85	71	63	D9	6C	66	09	C2	70	DC	63	E6	22	E8	08	›…qcÙlf.ÂpÜcæ"è.
0160h:	A4	55	5F	36	C2	64	1E	2B	B8	80	6A	A5	AC	17	92	41	¤U_6Âd.+¸€j¥¬.'A
0170h:	3C	21	2E	DF	CC	EA	75	9E	99	31	C4	D6	8C	AF	C7	04	<!.ßÌêuž™1ÄÖŒ¯Ç.
0180h:																	

Encrypted Cached Credentials
DK = PBKDF2(PRF, Password, Salt, c, dkLen)

Microsoft's implementation: MSDCC2=
PBKDF2(HMAC-SHA1, DCC1, username, 10240, 16)

Encrypted Cached Credentials:
Legend

Name	Value	Start	Size	Color	Comment
struct Header h		0h	96	Fg: Bg:	
ushort uname_len	16	0h	2	Fg: Bg:	
ushort domain_len	10	2h	2	Fg: Bg:	
ushort mail_nick_len	16	4h	2	Fg: Bg:	
ushort cn_len	28	6h	2	Fg: Bg:	
ushort u1	0	8h	2	Fg: Bg:	
ushort logon_script_len	0	Ah	2	Fg: Bg:	
ushort profile_path_len	0	Ch	2	Fg: Bg:	
ushort home_dir_len	0	Eh	2	Fg: Bg:	
uint user_sid	1163	10h	4	Fg: Bg:	
uint primary_group_id	513	14h	4	Fg: Bg:	
uint u2	2	18h	4	Fg: Bg:	
ushort group_sids_len	10	1Ch	2	Fg: Bg:	
ushort domain_netbios_name...	24	1Eh	2	Fg: Bg:	
FILETIME last_local_logon	04/25/2015 18:47:22	20h	8	Fg: Bg:	
ushort u3	4	28h	2	Fg: Bg:	
ushort u4	1	2Ah	2	Fg: Bg:	
uint u5	1	2Ch	4	Fg: Bg:	
ushort u6	1	30h	2	Fg: Bg:	
ushort u7	10	32h	2	Fg: Bg:	
uint u8	16	34h	4	Fg: Bg:	
uint u9	16	38h	4	Fg: Bg:	
ushort domain_name_len	18	3Ch	2	Fg: Bg:	
ushort email_len	36	3Eh	2	Fg: Bg:	
byte iv[16]	JO&|c›Ã"Ÿ—wæ°ÍR°	40h	16	Fg: Bg:	
byte cksum[16]	Àv¶gÖh7┘‡r•Ü ├m&▯	50h	16	Fg: Bg:	

Cached Logons: It used to be like this...

Windows 2003 / XP

The encryption algorithm is RC4.
The hash is used to verify authentication is calculated as follows:

```
DCC1 = MD4(MD4(Unicode(password)) .
LowerUnicode(username))
is
DCC1 = MD4(hashNTLM . LowerUnicode(username))
```

Usage in the attack

Before the attacks facilitated by pass-the-hash, we can only rejoice the "salting" by the username.

There are a number pre-computed tables for users as Administrator facilitating attacks on these hashes.

Cached Logons: Now it is like this!

Windows Vista / 2008 +

The encryption algorithm is AES128.

The hash is used to verify authentication is calculated as follows:

```
MSDCC2 = PBKDF2(HMAC-SHA1, Iterations,
DCC1, LowerUnicode(username))
```

with DCC 1 calculated in the same way as for 2003 / XP.

Usage in the attack

There is actually not much of a difference with XP / 2003! No additional salting.

PBKDF2 introduced a new variable: the number of iterations SHA1 with the same salt as before (username).

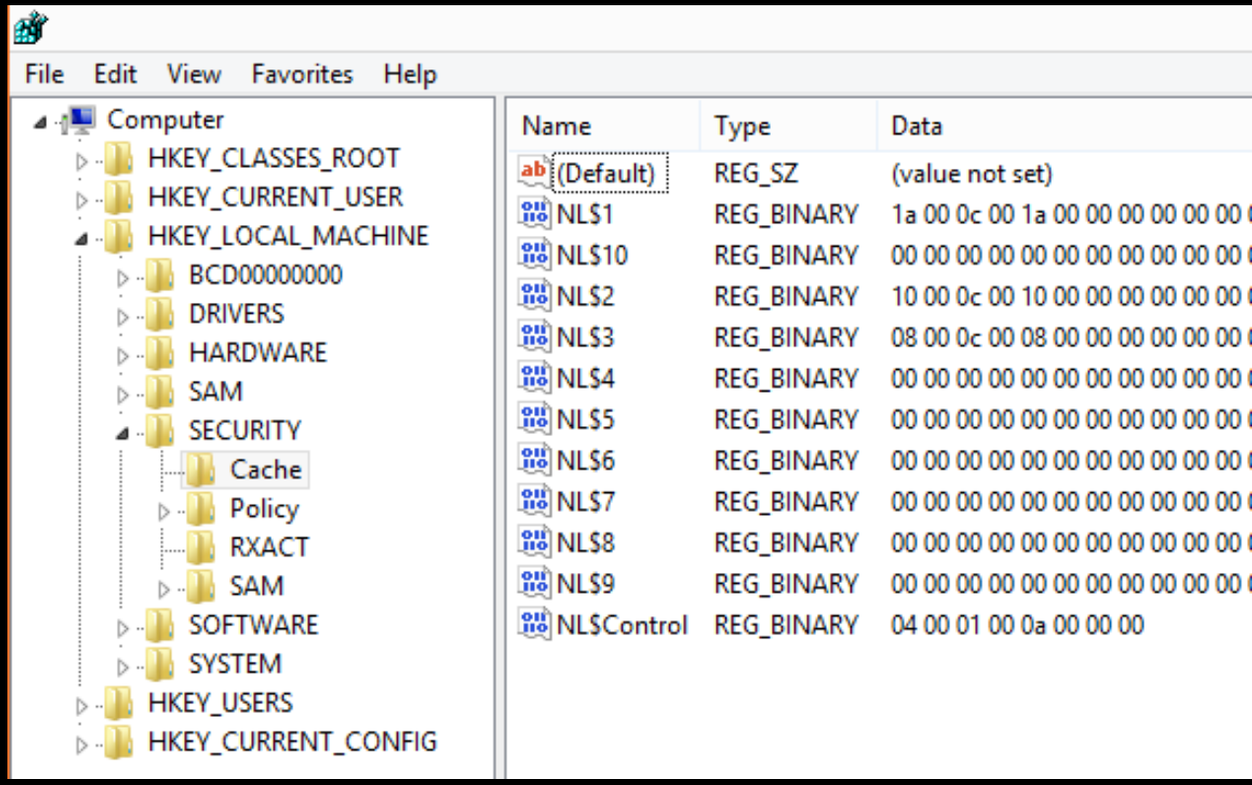
Cached Logons: Iterations

The number of iterations in PBKDF2, it is configurable through the registry:

```
HKEY_LOCAL_MACHINE\SECURITY\Cache
DWORD (32) NL$IterationCount
```

If the number is less than 10240, it is a multiplier by 1024 (20 therefore gives 20480 iterations)

If the number is greater than 10240, it is the number of iterations (rounded to 1024)



Getting the: cached data

MSDCC2

1. bootkey: classes from HKLM\SYSTEM\CCS\Control\Lsa + [class names for: Data, GBG, JD, Skew1] (+arrays' permutations)
   ```
   int[] permutationBootKey = new int[] { 0x8, 0x5, 0x4, 0x2, 0xb, 0x9, 0xd, 0x3, 0x0, 0x6, 0x1, 0xc, 0xe, 0xa, 0xf, 0x7 };
   ```
2. PolEKList: HKLM\SECURITY\Policy\PolEKList [default value]
3. lsakey: AES_DECRYPT(key, data) -> AES(bootkey, PolEKList)
4. NL$KM secret: HKLM\SECURITY\Policy\Secrets\NL$KM
5. nlkm_decrypted: AES_DECRYPT(lsakey, NL$KM secret)
6. Cache_Entry{id} -> HKLM\SECURITY\Cache\NL${id}
7. cache_entry_decrypted -> AES_DECRYPT(nlkm_decrypted, Cache_Entry{id})

Demo: Cached Credentials

+ getting access to user's secrets

Classic Data Protection API

- Based on the following components:

  Password, data blob, entropy

- Is not prone to password resets!

  Protects from outsiders when being in offline access

  Effectively protects users data

- Stores the password history

  You need to be able to get access to some of your passwords from the past

Conclusion: OS greatly helps us to protect secrets

Getting the: DPAPI Secrets

DPAPI (classic)

A. MasterKey
1. pwdhash = MD4(password) or SHA1(password)
2. pwdhash_key = HMACSHA1(pwdhash, user_sid)
3. PBKDF2(…, pwdhash_key,…), another elements from the file. Windows 10 no domain: SHA512, AES-256, 8000 rounds
4. Control - HMACSHA512

B. CREDHIST
1. pwdhash = MD4(password) or SHA1(password)
2. pwdhash_key = HMACSHA1(pwdhash, user_sid)
3. PBKDF2(…, pwdhash_key,…), another elements from the file. Windows 10 no domain: SHA512, AES-256, 8000 rounds
4. Control - HMACSHA512

C. DPAPI blob Algorithms are written in the blob itself.

DPAPI-NG

A. RootKey Algorithms Key derivation function: SP800_108_CTR_HMAC (SHA512) Secret agreement: Diffie-Hellman
B. DPAPI blob Key derivation: KDF_SP80056A_CONCAT
After getting the key, there is a need for decryption: Key wrap algorithm: RFC3394 (KEK -> CEK) Decryption: AES-256-GCM (CEK, Blob)

Demo: Classic DPAPI

+ getting access to user’s secrets in the domain

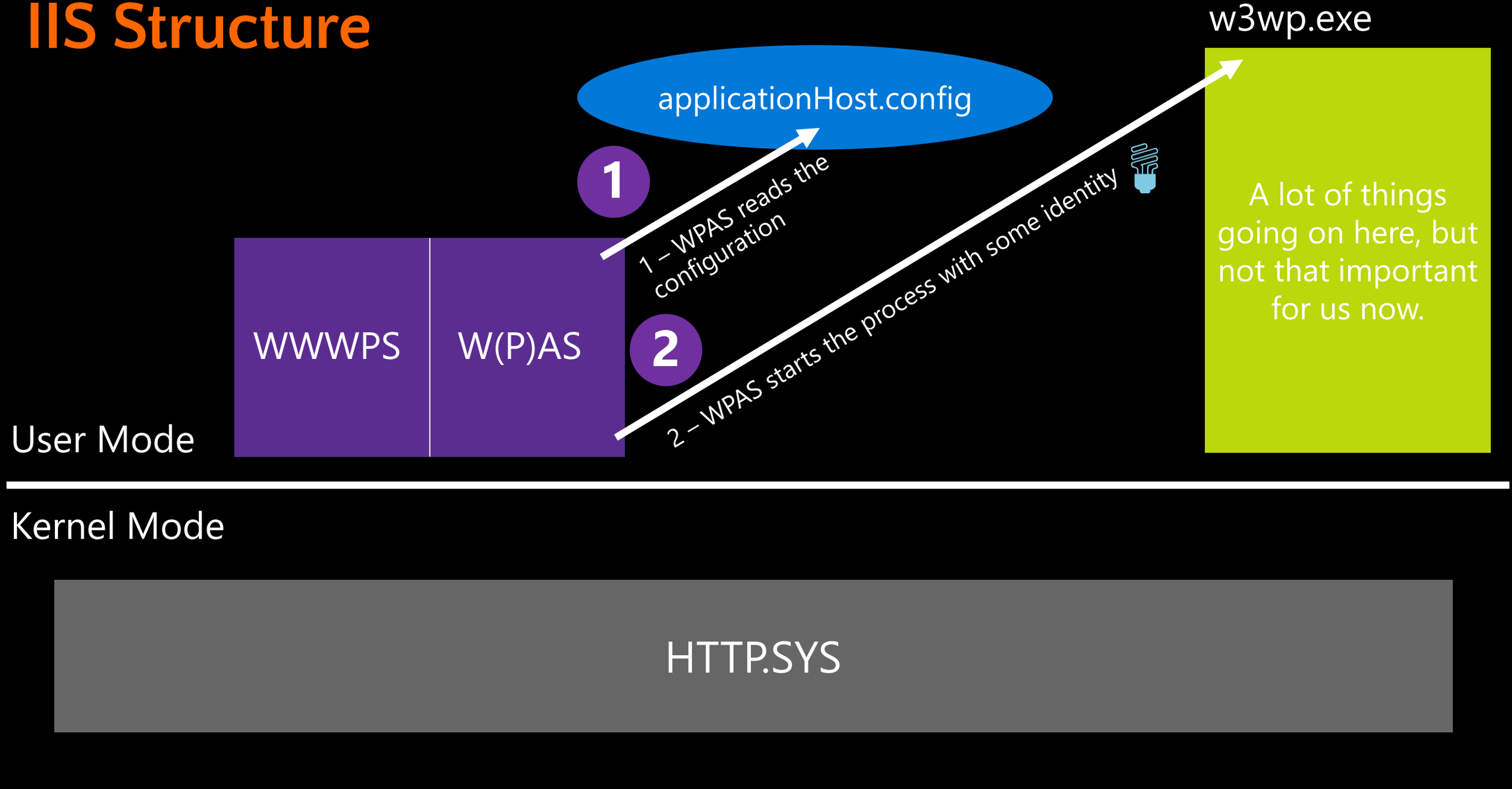
Demo: DPAPI Taken Further

+ Keepass

Demo: RDG Passwords

When centralization should be done
with a bit more awareness

IIS Structure



Application Pools

- Used to group one or more Web Applications

Purpose: Assign resources, serve as a security sandbox

- Use Worker Processes (w3wp.exe)

Their identity is defined in Application Pool settings
Process requests to the applications

- Passwords for AppPool identity can be ‘decrypted’ even offline

They are stored in the encrypted form in applicationHost.config

Conclusion: IIS relies it’s security on Machine Keys (Local System)

Demo: Application Pools

Getting password from IIS configuration

IISWasKey

+ extracting the data from the registry

Services

- Store configuration in the registry

Always need some identity to run the executable!

- Local Security Authority (LSA) Secrets

Must be stored locally, especially when domain credentials are used
Can be accessed when we impersonate to Local System

- Their accounts should be monitored

If you cannot use gMSA, MSA, use subscription for svc_ accounts (naming convention)

Conclusion: Think twice before using an Administrative account, use gMSA

Demo: Services

Getting password from LSA Secrets

Chasing the obvious: NTDS.DIT, SAM

To perform an analysis on NTDS.DIT the following information sources are needed from the domain controller:

- NTDS.DIT
- Registry hives (at least the SYSTEM hive)

SAM, ntds.dit are stored locally on the server's drive

They **do not** contain Passwords

They use **MD4** as a way of storing them

They are encrypted

The above means:

To read the clear text password you need to struggle!

Getting the: Hash

SAM

1. bootkey: classes from HKLM\SYSTEM\CCS\Control\Lsa + [class names for: Data, GBG, JD, Skew1] (+arrays' permutations)
2. F: HKLM\SAM\SAM\Domains\Account\ [F – value] string aqwerty = "!@#$%^&*()qwertyUIOPAzxcvbnmQQQQQQQQQQQQ)(*@&%\0"; string anum = "0123456789012345678901234567890123456789\0";
3. rchbootkey: MD5(string created after arytmetic functions with F, aqwerty, anum, bootkey)
4. hbootkey: RC4(key, data) -> RC4(rchbootkey, F)
5. MD5(…,hbootkey,…) -> RC4(…)-> DES(…, F) to get the hash (MD4)

Demo: SAM/NTDS.dit

Hash spree - offline

Credentials Security Takeways

- Offline access

  Cryptography that relies on keys stored in the registry is as safe as your offline access.

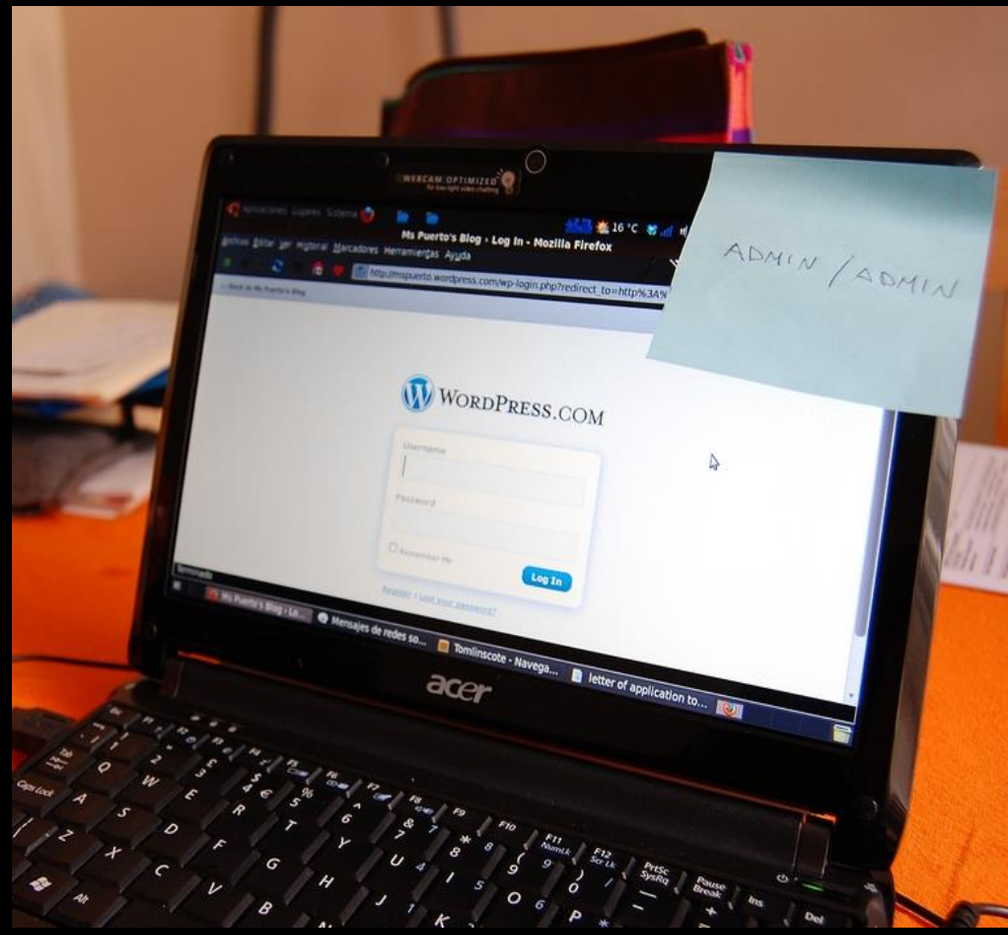
- Domain Admins

  We all know that they should log on to the Domain Controllers *only*.

  Who are they? Can we *trust* them?

- Mechanisms are safe

  …when extracted. In practice they are as safe as your approach.



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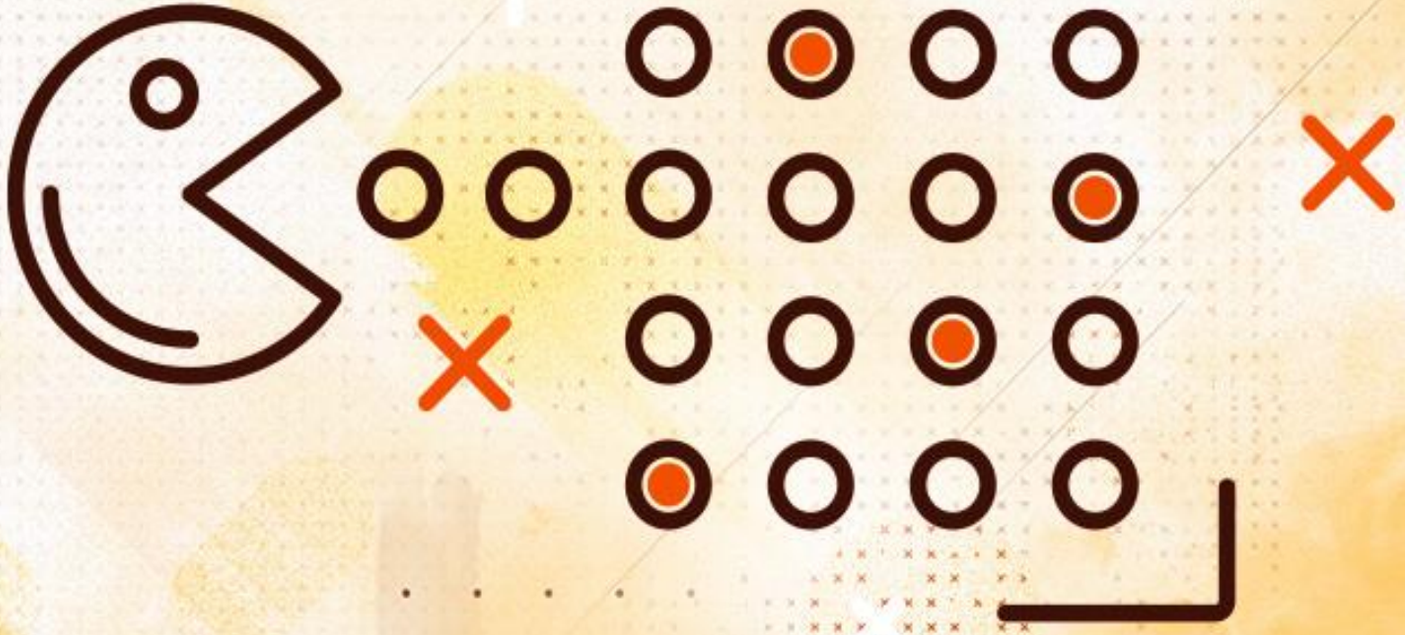

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