The SQL Server Crypto Detour

Banging your head when you don't know what to Google!

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About Me

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SPECTEROPS SO-CON 2025

How it all Started

With a Simple Request

How It All Started

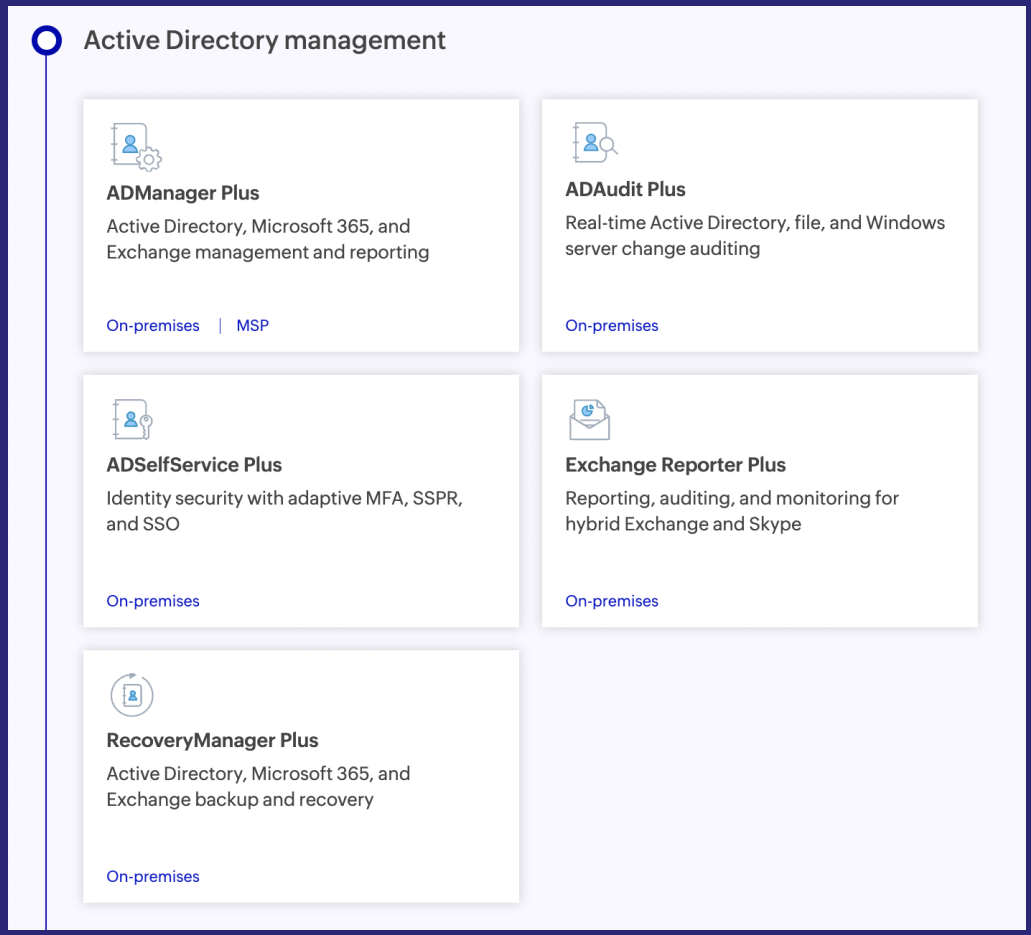
A New Job and a Red Team

- New role at SpecterOps as Service Architect in April 2024 (today is my anniversary \o/)
- One of the primary goals of my role is to drop into engagements and provide additional support, wherever needed
- Received a request from a Red Team to look at a database backup recovered for ManageEngine's ADSelfService product
- Database contained a lot of interesting information, however the interesting values were encrypted
- The request was simple.. "can you recover the encrypted data"?

How It All Started

What and Who is ManageEngine?

- A Zoho Company
- Provides a suite of tools to manage Active Directory
- Databases typically contain DA credentials ☺
- Can use different DB engines, but in our case, MSSQL Server was in use



How It All Started

What Was In The Backup?

- The issue presented was a MSSQL Server .bak file using MSSQL Server Database Encryption
- Recovery was a long shot, and some of the initial ideas I had were:
  - MSSQL crypto is likely linked to the DPAPI master key of the service account running SQL Server, so this backup won't be useful
  - MSSQL crypto may be linked to other keying material on the SQL Server, so backup won't be useful
  - It's unlikely that we will be able to recover any interesting data without access to SQL Server, so let's at least prove this for future reference
- Basically, I was being a Negative Nancy!

SQL Server Encryption Overview

Sounds Boring.. Because it is!

SQL Server Encryption Overview

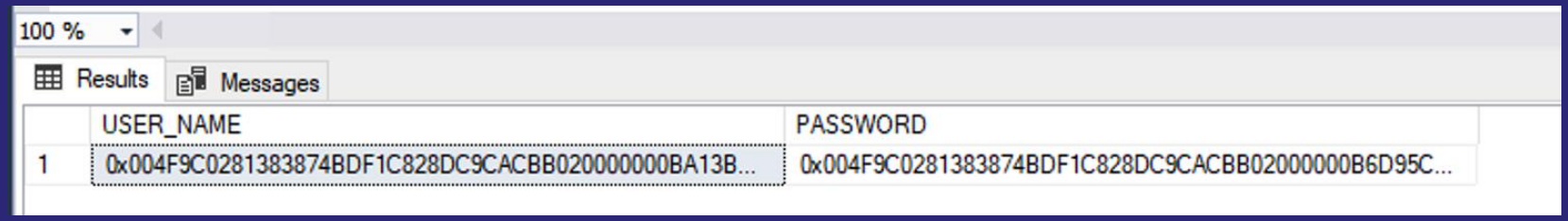
If It Sounds Boring.. That's Because It Is!

- SQL Server encryption is used to protect data within the database
- It does this transparently to the developer
- Once the database is unsealed, queries can be made and the crypto is handled by SQL Server
- Once the database is sealed (or a backup is made), the data is encrypted
- This is "Transparent Data Encryption" (TDE)

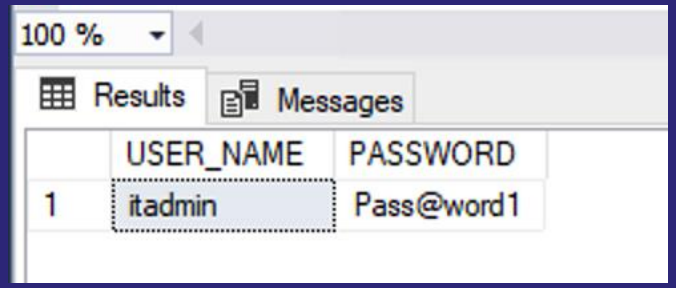
SQL Server Encryption Overview

If It Sounds Boring.. That's Because It Is!

- Data encrypted in a table looks like this:



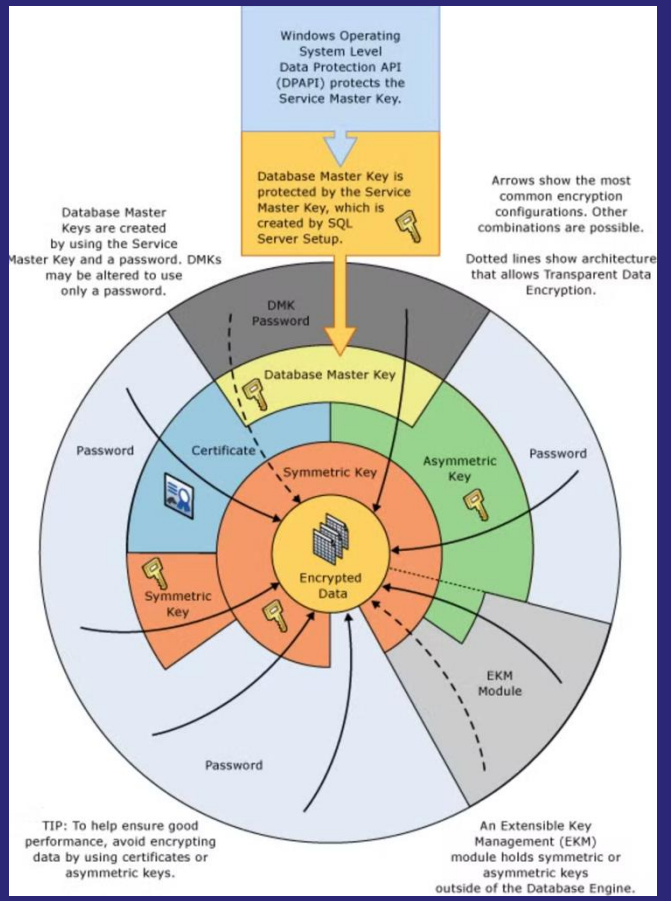
- Once unsealed, we see the decrypted values like this:



SQL Server Encryption Overview

Visualisation

- All starts with a Service Master Key (SMK) which is encrypted using DPAPI. The SMK is created during install



SQL Server Encryption Overview

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- All starts with a Service Master Key (SMK) which is encrypted using DPAPI. The SMK is created during install
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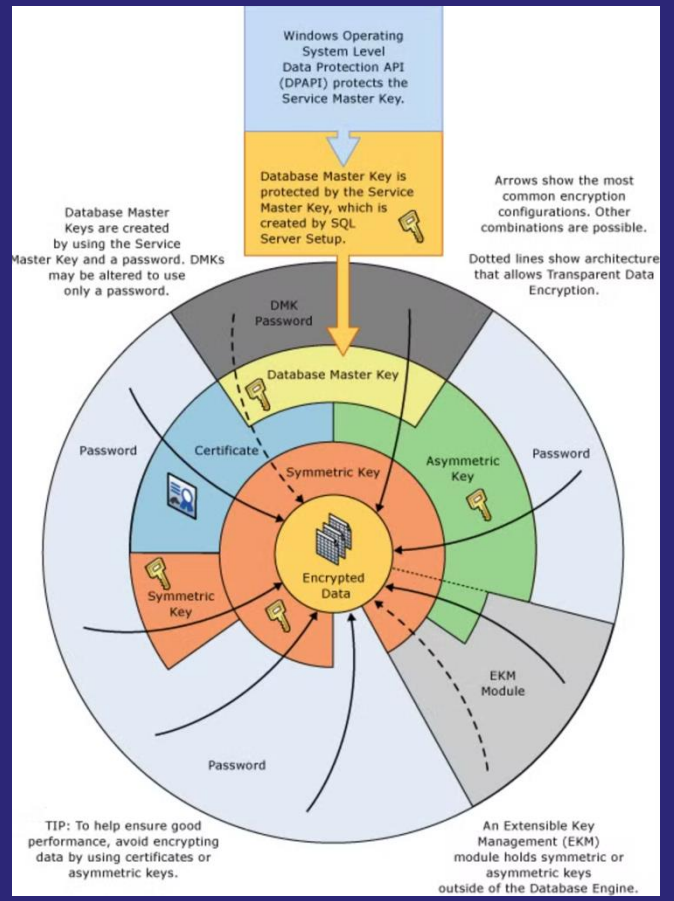
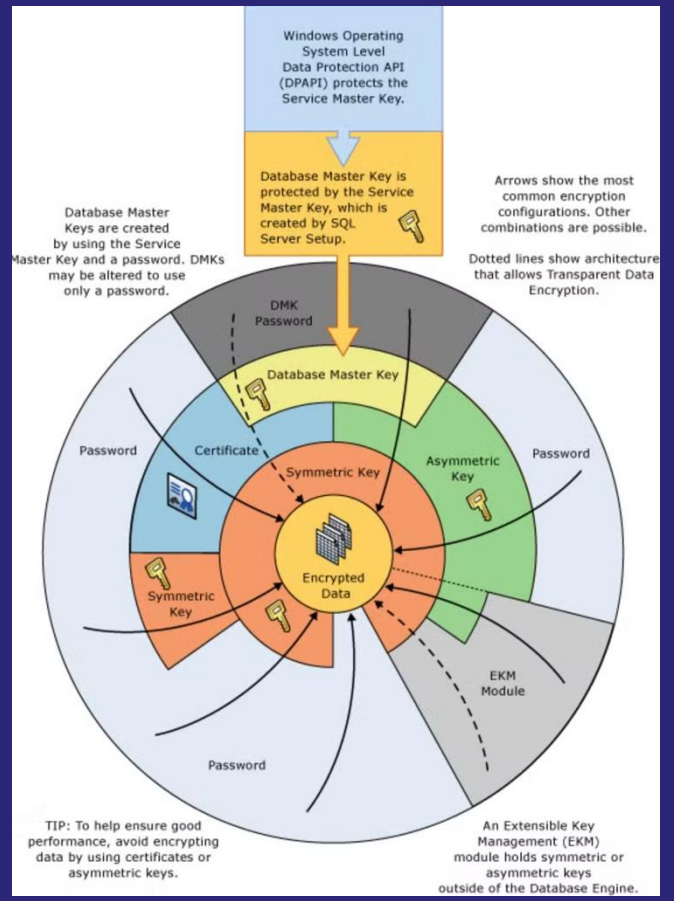


SQL Server Encryption Overview

Visualisation

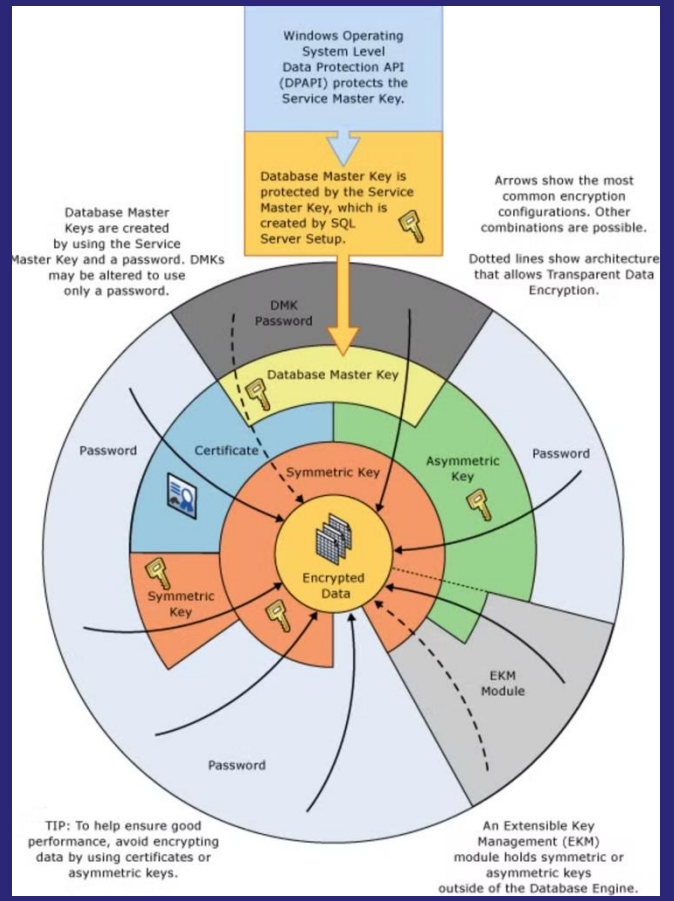
- All starts with a Service Master Key (SMK) which is encrypted using DPAPI. The SMK is created during install
- A Database Master Key (DMK) is encrypted by the SMK
- A Certificate or Async Key is encrypted by the DMK



SQL Server Encryption Overview

Visualisation

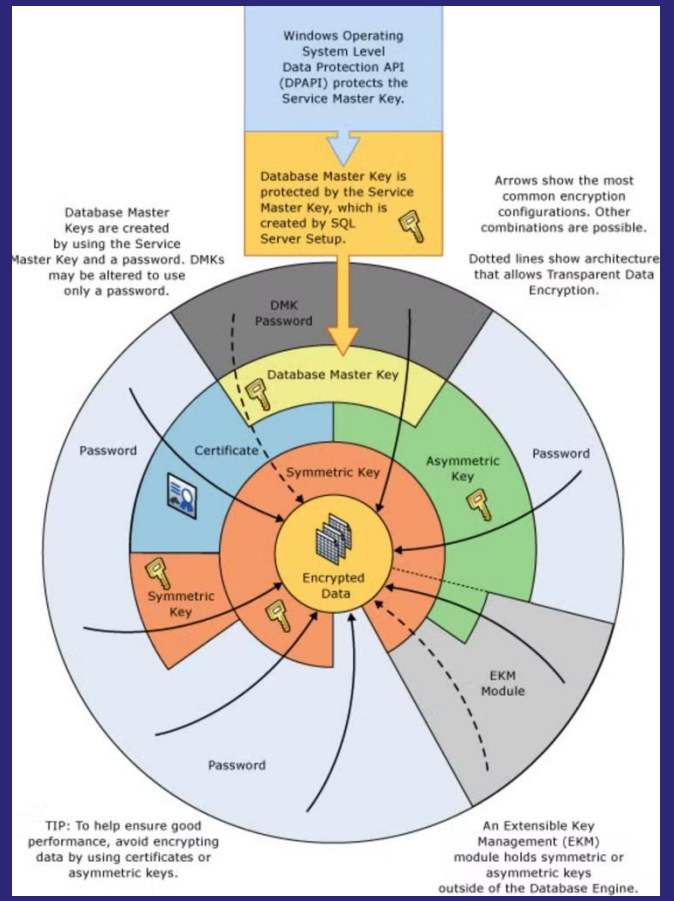
- All starts with a Service Master Key (SMK) which is encrypted using DPAPI. The SMK is created during install
- A Database Master Key (DMK) is encrypted by the SMK
- A Certificate or Async Key is encrypted by the DMK
- The symmetric key is encrypted by the Certificate or Async Key



SQL Server Encryption Overview

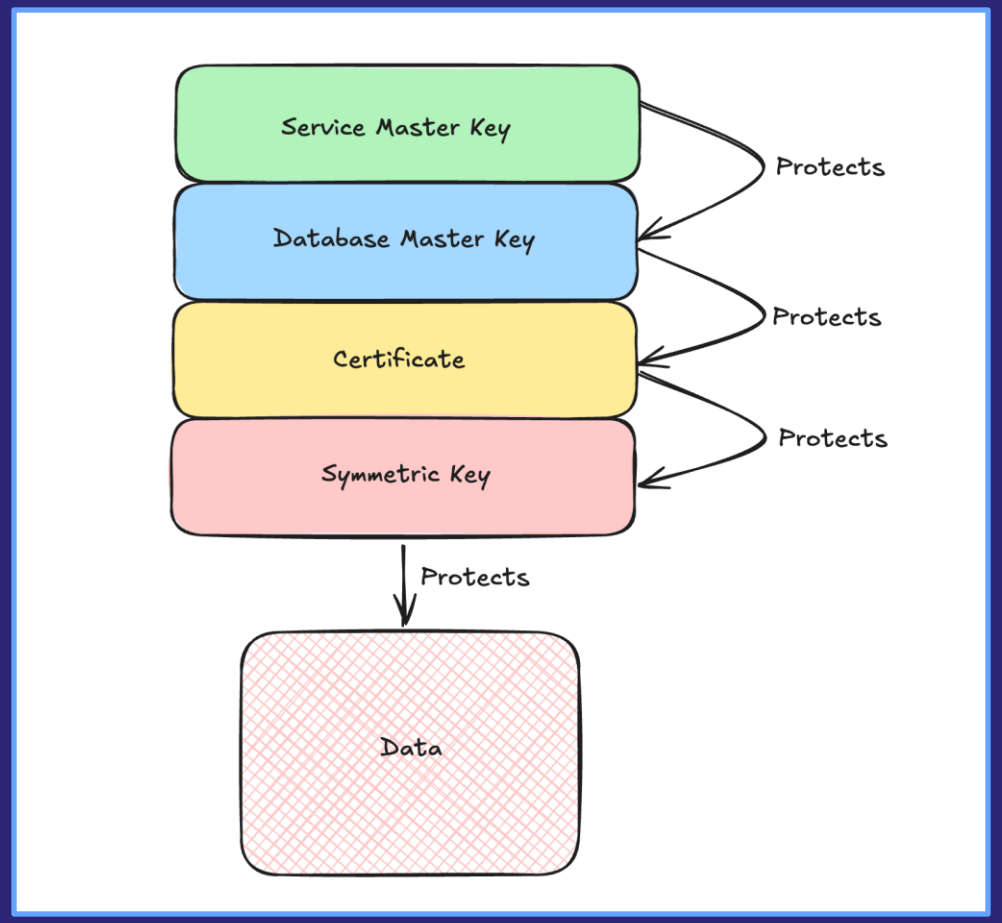
Visualisation

- All starts with a Service Master Key (SMK) which is encrypted using DPAPI. The SMK is created during install
- A Database Master Key (DMK) is encrypted by the SMK
- A Certificate or Async Key is encrypted by the DMK
- The symmetric key is encrypted by the Certificate or Async Key
- Symmetric key used to encrypt data



SQL Server Encryption Overview

Breaking The Crypto Stack



If we can compromise any layer of the SQL Crypto stack, each layer below will fall.

SQL Server Encryption Overview

TSQL for TDE

- To start using SQL Server Encryption, we first create the Database Master Key, which is encrypted with the SMK:

```
USE CryptoDB;
CREATE MASTER KEY ENCRYPTION BY PASSWORD='Password123'
```

- The generated Database Master Key row can be viewed using:

```
SELECT * FROM sys.symmetric_keys
```

SQL Server Encryption Overview

TDE Tables

```
SELECT * FROM sys.symmetric_keys
```

- Unfortunately, you can’t find the generated key value in the table:

Results | Messages

	name	principal_id	symmetric_key_id	key_length	key_algorithm	algorithm_desc	create_date	modify_date	key_guid	key
1	##MS_DatabaseMasterKey##	1	101	256	A3	AES_256	2024-06-16 18:51:13.390	2024-06-16 18:51:13.390	EEB18100-BD00-466B-8416-B2CC5143BDE3	NU

- Instead, it is found in sys.key_encryptions within crypt_property (in some blob form)

100 %

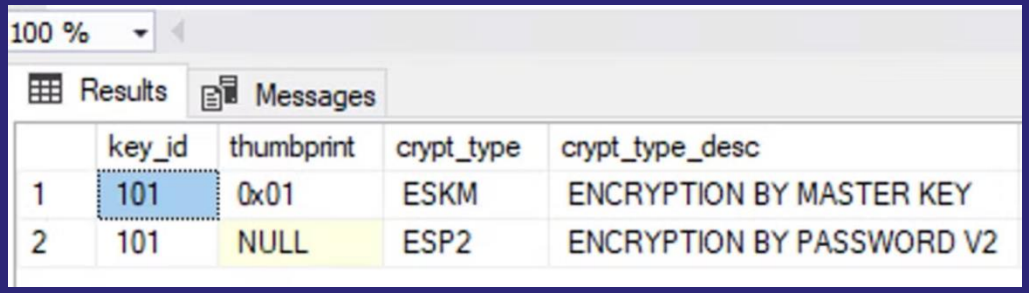
Results | Messages

	key_id	thumbprint	crypt_type	crypt_type_desc	crypt_property
1	101	0x01	ESKM	ENCRYPTION BY MASTER KEY	0x450CE934E626B80C4E3492785AE61AC93A8255A151CC866...
2	101	NULL	ESP2	ENCRYPTION BY PASSWORD V2	0xA9B49BF739BBC8BBF7977F941732F647DABC47B7ACE5E7...

SQL Server Encryption Overview

TDE Tables

- crypt_type and crypt_type_desc fields in sys.key_encryptions look interesting



	key_id	thumbprint	crypt_type	crypt_type_desc
1	101	0x01	ESKM	ENCRYPTION BY MASTER KEY
2	101	NULL	ESP2	ENCRYPTION BY PASSWORD V2

- Microsoft provide a table describing each crypt_type, but it's vague

crypt_type	char(4)	Type of encryption: ESKS = Encrypted by symmetric key ESKP, ESP2, or ESP3 = Encrypted by password EPUC = Encrypted by certificate EPUA = Encrypted by asymmetric key ESKM = Encrypted by master key

Fire Up The Debugger H4xx0rz… We're Going Low Level

Low Level Analysis

- As we know, the best method of analysis is to set up a lab
- Lab setup consisted of:
  - SQL Server 2008
  - SQL Server 2019
- API Monitor
- x64Dbg (WinDBG was being a pain to install from the store)

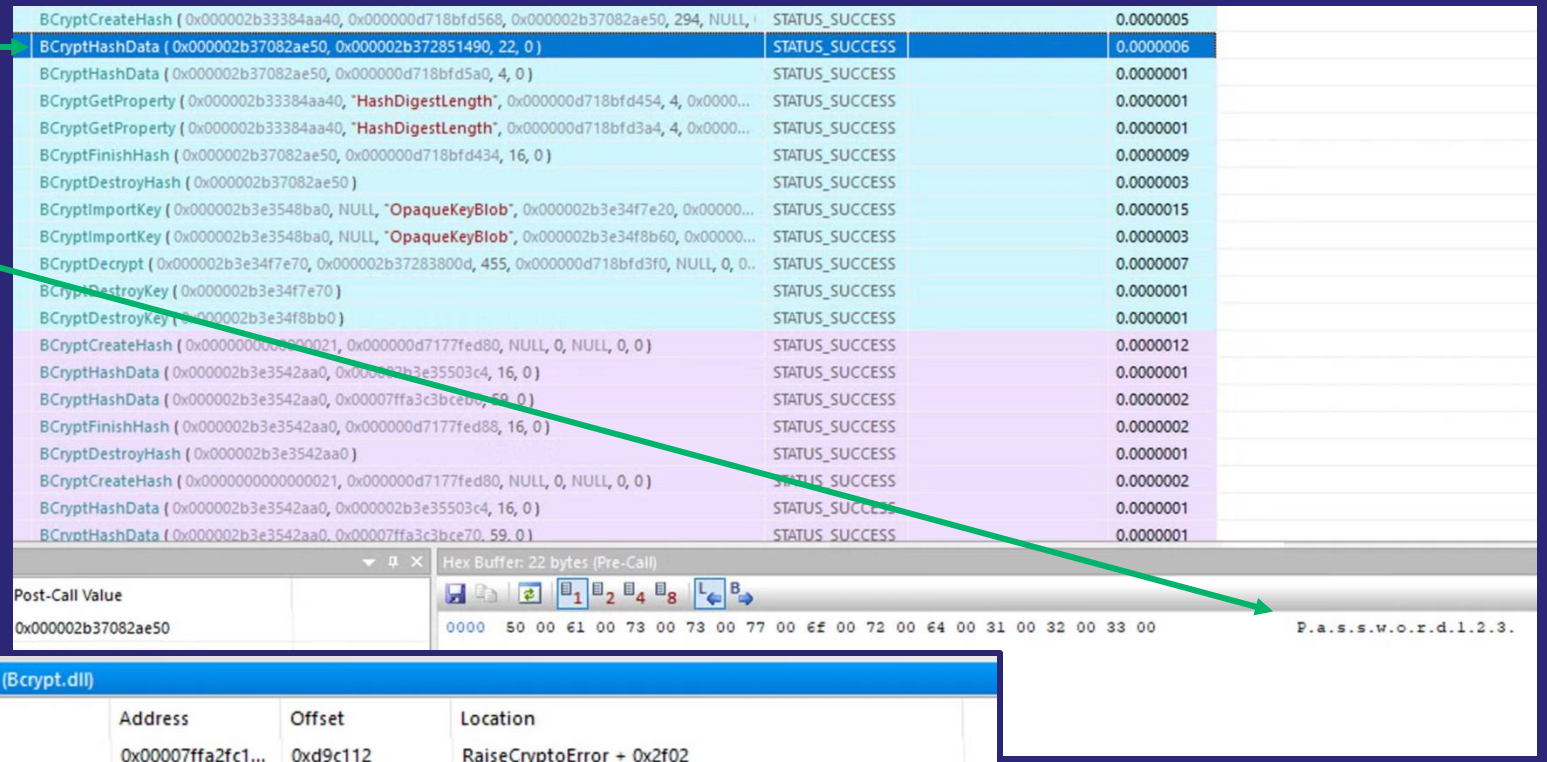
Low Level Analysis

APIMonitor

BCryptHashData Used

Password Parameter Shown

Call stack shows sqllang.dll is the caller of Bcrypt API



Low Level Analysis

sqllang.dll

- Call stack shows sqllang.dll uses Bcrypt APIs when calling encryption

Call Stack: BCryptHashData (Bcrypt.dll)

#	Module	Address	Offset	Location
1	sqllang.dll	0x00007ffa2fc1...	0xd9c112	RaiseCryptoError + 0x2f02
2	sqllang.dll	0x00007ffa2fc2...	0xdad37e	ComparePartialThumbPrint + 0x34e
3	sqlmin.dll	0x00007ffa01ea...	0x515b94	SMD::UnregisterResumableOibSourceRowsets + 0xd374
4	sqllang.dll	0x00007ffa2fc7...	0xdffecf	GetCredentialSecretFromLogicalMaster + 0x19c6f

- And symbols are available from Microsoft

```
PS C:\Program Files (x86)\Windows Kits\10\Debuggers\x64> .\symchk.exe C:\tools\sqlmin.dll /s SRV*c:\symbols\*http://msdl
.microsoft.com/download/symbols

SYMCHK: FAILED files = 0
SYMCHK: PASSED + IGNORED files = 1
PS C:\Program Files (x86)\Windows Kits\10\Debuggers\x64>
```

Low Level Analysis

Follow The Data

- Our plan to dig further becomes:
    1. Add a bunch of breakpoints to Crypt API’s
    2. Create a new database master key
    3. Hopefully break on a crypto API call
    4. Review the encrypted data

Low Level Analysis

Follow The Data

- We hit a breakpoint on CryptUnprotectData

```
crypt32.CryptUnprotectData
sqllang.private: class CSECCryptoError __cdecl CSECDPAPIEncryption::InternalUnprotectDataWindows(struct _CRYPTOAPI_BLOB &, unsigned short **, unsigned long, st
sqllang.protected: class CSECCryptoError __cdecl CSECDPAPIEncryption::InternalUnprotectData(struct _CRYPTOAPI_BLOB &, unsigned short **, unsigned long, struct
sqllang.public: virtual class CSECCryptoError __cdecl CSECMachineAccountEncryption::UnprotectData(struct _CRYPTOAPI_BLOB &, unsigned short **, struct _CRYPTOAP
sqllang.private: class CSECCryptoError __cdecl CSECDPAPIEncryptionMechanism::DecryptUsingDPAPI(struct _CRYPTOAPI_BLOB &, unsigned short **, enum CSECEncryption
sqllang.private: class CSECCryptoError __cdecl CSECDPAPIEncryptionMechanism::DecryptUsingMachineAccount(struct _CRYPTOAPI_BLOB &, unsigned short **)+2B
sqllang.public: virtual class CSECCryptoError __cdecl CSECDPAPIEncryptionMechanism::GetDecryptedSMK(struct _CRYPTOAPI_BLOB &, int)+A4
sqllang.public: class CSECCryptoError __cdecl CSECServiceMasterKey::Initialize(class IMemObj *, class IMetadataAccess *, int, int, int)+369
sqllang.public: static class CSECCryptoError __cdecl CSECDBMasterKey::Decrypt(class IMemObj *, class IMetadataAccess *, class IMEDObfusKey *, class CSECCryptoC
```

- The stack trace tells a story:
  - CSECDBMasterKey::Decrypt
  - CSECServiceMasterKey::Initialize
- We know that the Service Master Key (SMK) protects the DB Master Key (DMK), and the stack trace reflects this too

Low Level Analysis

Follow The Data

- Analysis of the data passed to CryptUnprotectData matches the newly created key value in the master.sys.key_encryptions table
- The call also includes optional entropy, which we find in the registry:
  - HKLM\SOFTWARE\Microsoft\Microsoft SQL Server\MSSQL14.MSSQLSERVER\Security

Name	Type	Data
(Default)	REG_SZ	(value not set)
Entropy	REG_BINARY	bd 39 c4 a6 38 5b aa 37 94 bb e1 6f aa cd 3e 33 06 91 14 73 54 eb fb c5 ab db d8 fb b1 48 3b 37 2d

Low Level Analysis

Recovering the SMK

- This means that if we have execution rights on a machine running SQL Server, we can recover the Service Master Key using something like:

```
// Read registry key Entropy Value
var rk = Registry.LocalMachine.OpenSubKey(@"SOFTWARE\Microsoft\Microsoft SQL Server\MSSQL14.MSSQLSERVER\Security");
byte[] entropy = (byte[])rk.GetValue("Entropy", new byte[] { 0x41 });

// SQL Encrypted SMK (minus the first 8 bytes)
byte[] encryptedData = new byte[]
{
   0x01, 0x00, 0x00, 0x00, 0xD0, 0x8C, 0x9D, 0xDF, 0x01, 0x15, 0xD1, 0x11, 0x8C, 0x7A, 0x00, 0xC0, 0x4F, …
};

// Decrypt key
byte[] data = ProtectedData.Unprotect(encryptedData, (byte[])entropy, DataProtectionScope.LocalMachine);
```

Low Level Analysis

But That Doesn’t Help!

- Unfortunately, this doesn’t help with our original quest of recovering encrypted data from a SQL Server backup.
- For this we need the clear-text database master key

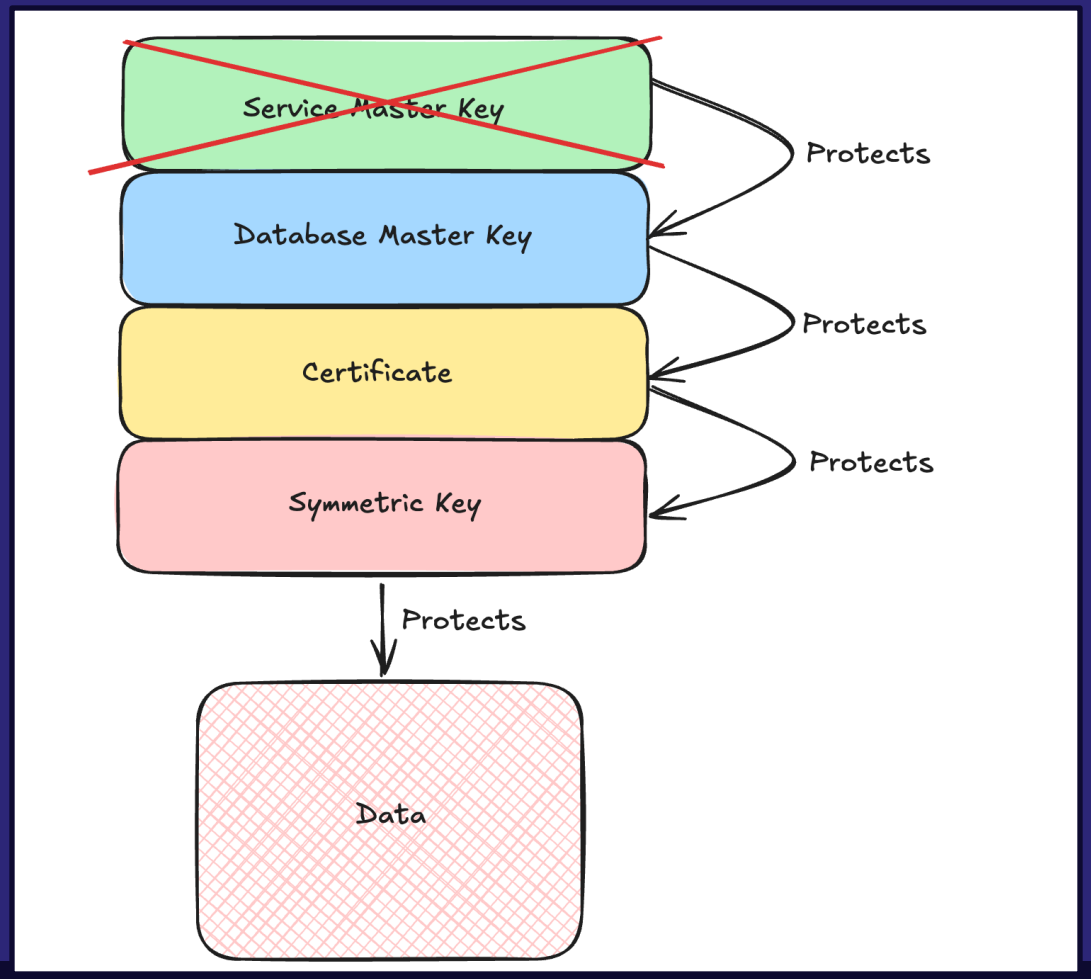
Low Level Analysis

But That Doesn’t Help!

- Unfortunately, this doesn’t help with our original quest of recovering encrypted data from a SQL Server backup.
- For this we need the clear-text database master key
- Which we don’t have ☹

Low Level Analysis

Recovering the SMK



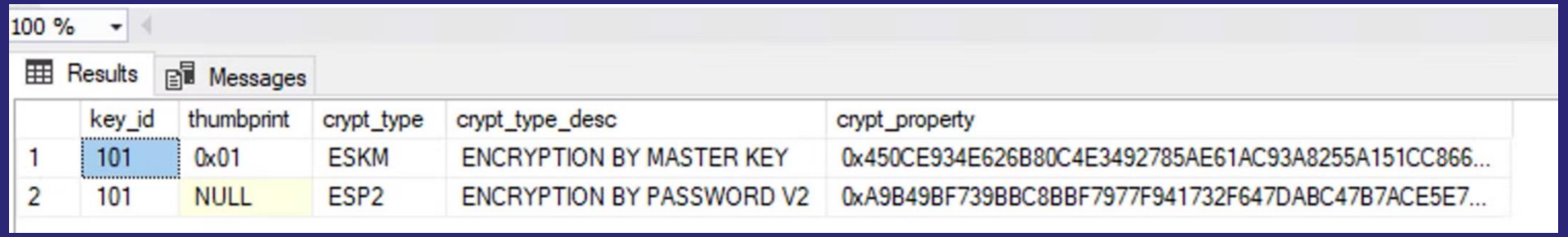
We can rule out the SMK from our quest as this only lives on the MSSQL server instance, not in the database backup

Low Level Analysis

But Wait…

- But wait…
- Remember when we initialized the database master key…
- What was that password for?

```
CREATE MASTER KEY ENCRYPTION BY PASSWORD='Password123'
```



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Low Level Analysis

Some More Questions

- Some more questions:
  - How is this password tied to the Service Master Key?
  - Is the password ever stored in the database?
  - Is all the keying material for this password stored in a database backup?
  - Can we somehow bruteforce this key?
- Let’s find out

Low Level Analysis

Finding Out

- So, we add another breakpoint to BCryptHashData and recreate the APIMonitor hook we observed before
- This breaks along with the entered password:

Low Level Analysis

Finding Out

- The stack trace reveals an interesting method name:
  - CMEDProxyObfusKey::SearchEncryptionByUserData

```
bcrypt.BCryptHashData
sqllang.public: class CSECCryptoError __cdecl CSECHash::HashData(struct SECBytes &)+42
sqllang.int __cdecl ComparePartialThumbPrint(unsigned char *, unsigned long, unsigned char *, unsigned long, void *, enum EMDCryptoPropertyType)+34E
sqlmin.public: virtual bool __cdecl CMEDProxyObfusKey::SearchEncryptionByUserData(unsigned char *, unsigned long, enum EMDCryptoPropertyType &, unsigned char *, unsigned long &,
sqllang.public: virtual enum EXRetType __cdecl CStmtOpenDBMasterKey::XretExecute(class CCompExecCtxtStmt const &, class CExecuteStatement *, class CMsqlExecContext *) const+4EF
sqllang.private: int __cdecl CMsqlExecContext::ExecuteStmts<1, 1>(class CO_Statement &, class CCompExecCtxt const &, unsigned long, bool, bool *)+350
sqllang.public: bool __cdecl CMsqlExecContext::FExecute(class CCompExecCtxt const &, bool, class CParamExchange *, unsigned long, bool)+733
sqllang.public: virtual void __cdecl CSQLSource::Execute(class CCompExecCtxtBasic const &, class CParamExchange *, unsigned long)+474
sqllang.enum ECommandResult __cdecl process_request(class IBatch *, class SNI_Conn *, enum RequestType)+815
sqllang.enum ECommandResult __cdecl process_commands_internal(class IBatch *, class CNetConnection *, class CPhysicalConnection *, class ILogonSession *, int &, int &)+122
```

- “Obfus” within a class name is always a good path to follow!

Low Level Analysis

Disassembling SearchEncryptionByUserData

- We start the disassembly of SearchEncryptionByUserData
- Within this method we find a comparison of a “thumbprint”:

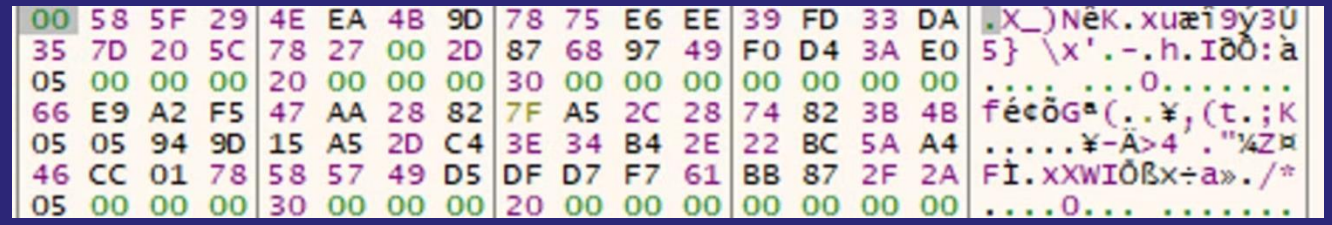
```
if (((EVar2 == EVar3) ||
    (((EVar2 == 1 || (EVar2 + 0xfffffff5 < 2)) && ((EVar3 == 1 || (EVar3 + 0xfffffff5 < 2))))
    ) && (iVar5 = ComparePartialThumbPrint
                            (param_1,param_2,*ppuVar8,*(ulong *)(ppuVar8 + 1),param_8,EVar3),
         iVar5 != 0)) {
  *param_3 = *(EMDCryptoPropertyType *)((longlong)ppuVar8 + 0x1c);
  if (uVar1 <= uVar9) {
```

- Another breakpoint later reveals that the third value passed to this function is a blob of data we haven’t seen so far…

Low Level Analysis

What is this thumbprint?

- This is a hex encoded value we find in the database sys.sysobjkeycrypts (require DAC connection to access this table)



00	58	5F	29	4E	EA	4B	9D	78	75	E6	EE	39	FD	33	DA	.X_)NêK.xuæî9ý3Ú
35	7D	20	5C	78	27	00	2D	87	68	97	49	F0	D4	3A	E0	5} \x'.-.h.IðÔ:à
05	00	00	00	20	00	00	00	30	00	00	00	00	00	00	00	....0.....
66	E9	A2	F5	47	AA	28	82	7F	A5	2C	28	74	82	3B	4B	fé¢õGª(..¥,(t.;K
05	05	94	9D	15	A5	2D	C4	3E	34	B4	2E	22	BC	5A	A4	.....¥-Ä>4´."¼Z¤
46	CC	01	78	58	57	49	D5	DF	D7	F7	61	BB	87	2F	2A	FÌ.xXWIÕßx÷a».‡/*
05	00	00	00	30	00	00	00	20	00	00	00	00	00	00	00	....0... .....

- Looks like the sys.key_encryptions table but with thumbprint populated:

	class	id	thumbprint	type	crypto	status
1	24	101	0x00585F294EEA4B9D7875E6EE39FD33DA357D205C7827002D87689749F0D43AE0	ESP2	0x66E9A2F547AA28827FA52C2874823B4B0505949D15A52DC4...	0
2	24	101	0x01	ESKM	0x871127C0F150FB46DAFA94699AEA5AE22F39924AB1E69AE9...	0

Low Level Analysis

ComparePartialThumbPrint

1. The decryption password is hashed

Decompile: ComparePartialThumbPrint - (sqllang.dll)

```
67      local_60 = password;
68      local_58 = passwordLength;
69      CSECHash::HashData((CSECHash *)&local_c8,&local_f8);
70      local_48 = local_e0;
```

Low Level Analysis

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2. The password hash is salted

Decompile: ComparePartialThumbPrint - (sqllang.dll)

```
82              (**(code **)(**(longlong **)(uVar1 + 8) + 0x28))();
83            }
84          }
85          CSECHash::Salt((CSECHash *)&local_c8,(ulong)&local_f8);
86          local_48 = local_e0;
87          if ((int)local_f8.Password == 0) {
```

Low Level Analysis

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84          }
85          CSECHash::Salt((CSECHash *)&local_c8,(ulong)&local_f8);
86          local_48 = local_e0;
87          if ((int)local_f8.Password == 0) {
```

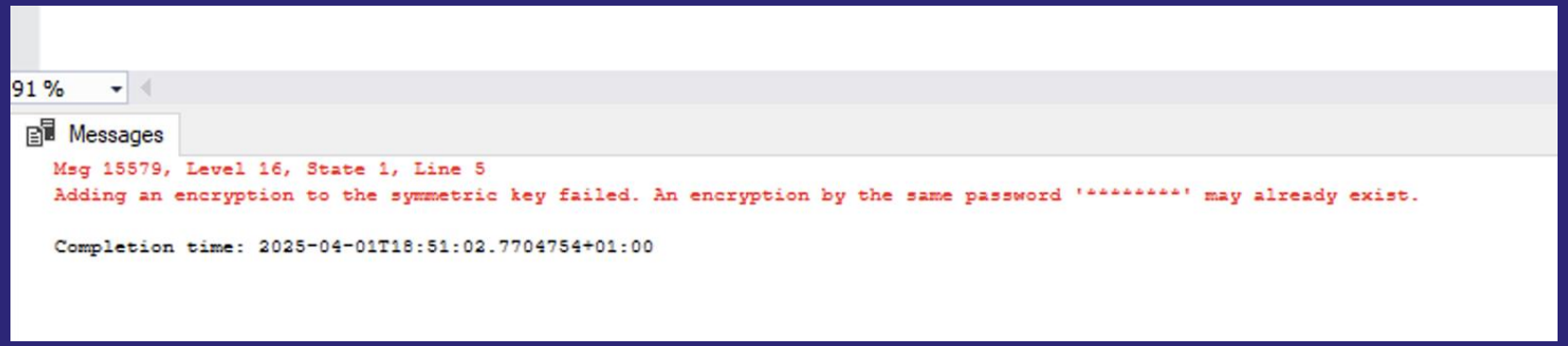
3. The hashed and salted password is compared against the DB thumbprint

```
local_60 = thumbprint;
local_58 = thumbprintLength;
CSECHash::VerifyHash((CSECHash *)&local_c8,&local_f8);
if (local_e0 != 0) {
  uVar1 = local_e0 & 0xfffffffffffe000;
```

Low Level Analysis

Why does this exist?

- Validates if same password is in use
- Adding new symmetric key with same password fails:



Low Level Analysis

ComparePartialThumbPrint

- If our hypothesis is correct, this means:
  - All the keying material is in the database (and therefore the backup)
  - Nothing in the thumbprint ties the DMK to the SMK, therefore DPAPI isn't a factor
- But what is the algo used to hash the password?
  - Depends on the version of SQL Server ORIGINALLY used to create the DMK

Low Level Analysis

Crypto Versions

- ESP2 – Observed with SQL Server 2012
- ESKP – Observed with SQL Server 2008

- With breakpoints added to BCryptHashData, we find that:
  - ESP2:
    - SHA-512 Thumbprint
    - Salted with 8 bytes
    - Result truncated to 24 bytes

Low Level Analysis

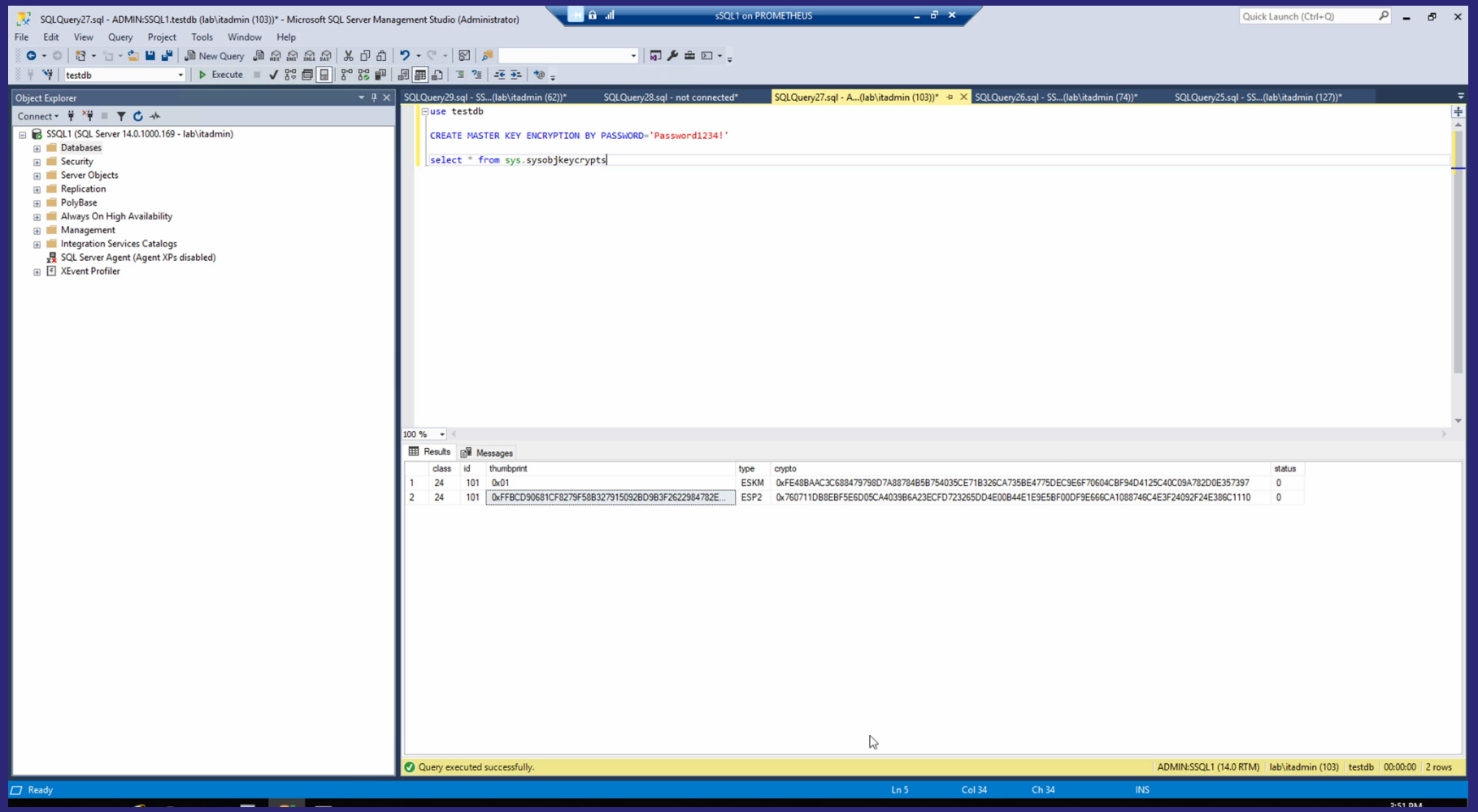
Bruteforce

- ESP2 needs a custom format due to truncation, but we can do it easily in JtR:

```
[List.Generic:dynamic_2020]
Expression=sha512(utf16le($p).$s) (hash truncated to length 24)
Flag=MGF_SALTED
Flag=MGF_FLAT_BUFFERS
Flag=MGF_INPUT_24_BYTE
SaltLen=8
Func=DynamicFunc__clean_input_kwik
Func=DynamicFunc__setmode_unicode
Func=DynamicFunc__append_keys
Func=DynamicFunc__setmode_normal
Func=DynamicFunc__append_salt
Func=DynamicFunc__SHA512_crypt_input1_to_output1_FINAL
Test=$dynamic_2020$E45AF6FA6601E13A8F2B620FF8A859AE4B459B848D06F5C7$HEX$28E3C098
```

Low Level Analysis

Demo



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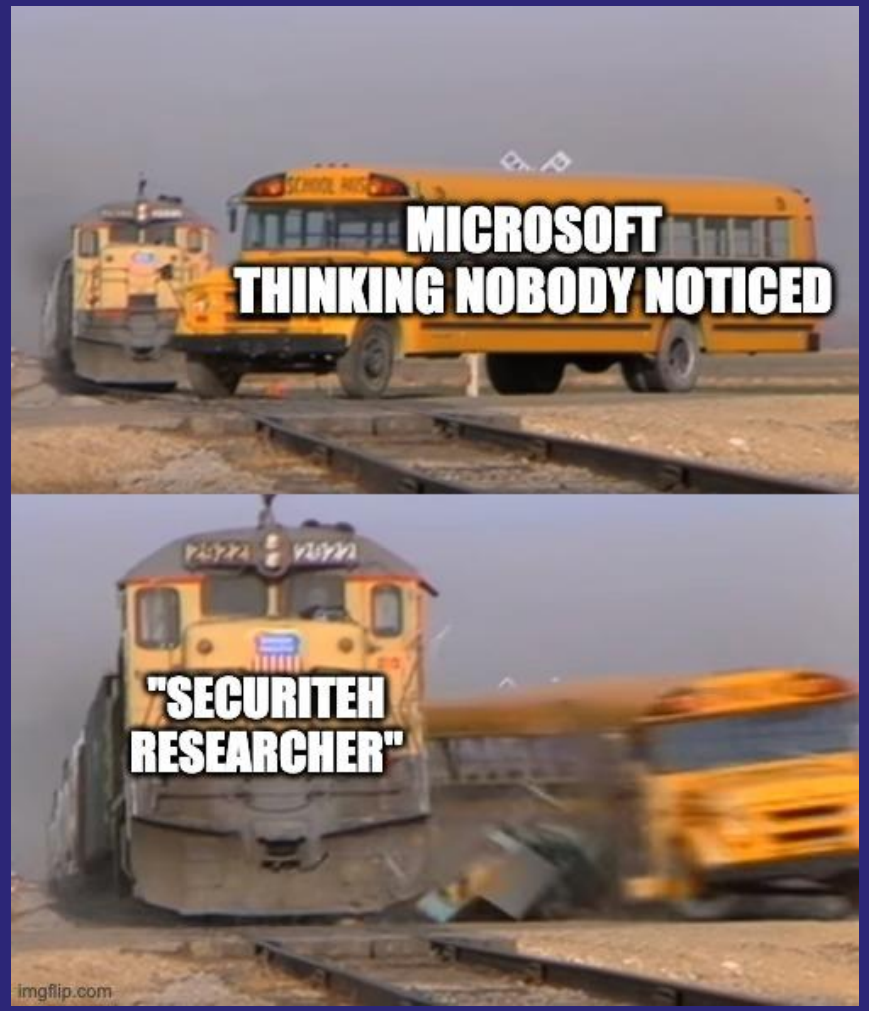
- By breakpoints added to BCryptHashData, we find that:
  - ESP2:
    - SHA-512 Thumbprint
    - Salted with 8 bytes
    - Result truncated to 24 bytes
  - **ESKP:**
    - **MD5 Thumbprint**
    - **Salted with 4 bytes**



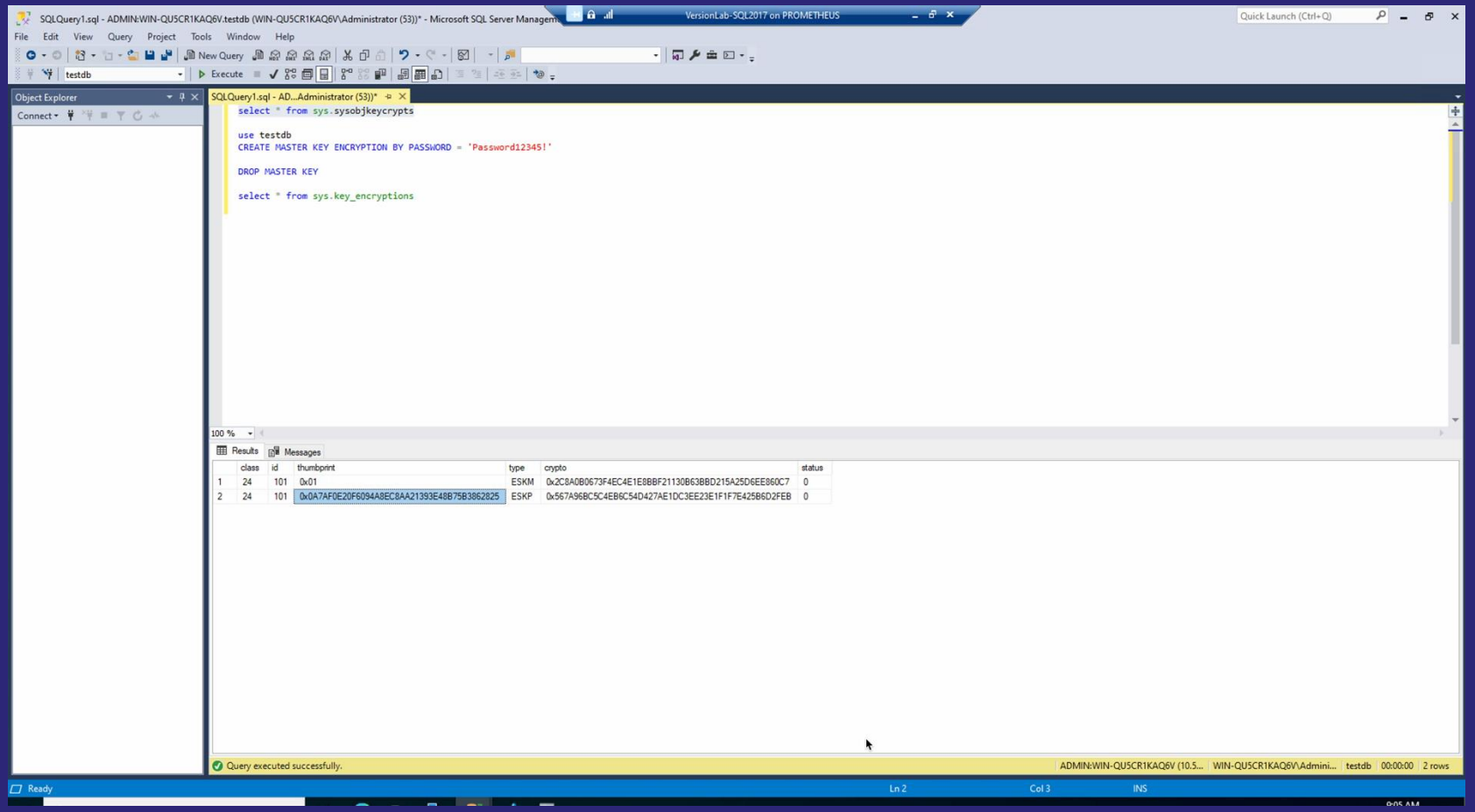
Low Level Analysis

Bruteforce

- We can bruteforce ESKP thumbprints with Hashcat:
  - md5(utf16le($pass).$salt)

Low Level Analysis

Demo



Low Level Analysis

Crypto Versions

- So what? Nobody uses SQL Server 2008 anymore?!
- Well:
  - Of course they do!
  - But even if they all upgraded:
    - Keys amended are appended (hey, that rhymes), leaving old ESKP (MD5) keys in the database
    - Upgrading SQL Server doesn’t rotate the encryption key

Low Level Analysis

Crypto Versions

```
CREATE MASTER KEY ENCRYPTION BY PASSWORD = 'Password123456!'
ALTER MASTER KEY ADD ENCRYPTION BY PASSWORD='Wibble11111!'
```

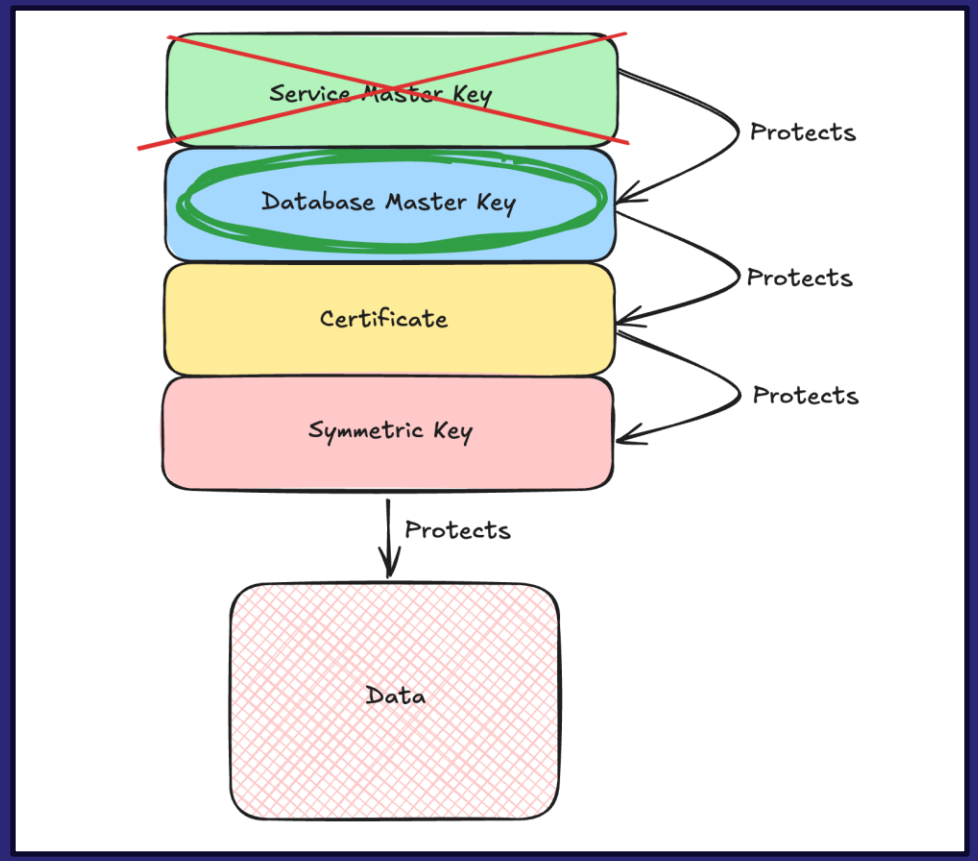
100 %

Results | Messages

	class	id	thumbprint	type	crypto	status
1	24	101	0x01	ESKM	0x51316AB020D68A8C8EBF675E638C2EAC5138C0146C0E5F9A	0
2	24	101	0x757A5C21D9CE6DC2B84F48EF40D450961E094CB5	ESKP	0xCD61A83664617185819AD8AE5B50FCB36B5FC250A84FD54B	0
3	24	101	0xECD270F950E0C92F9DC1986144D48A455513AD0D	ESKP	0x165837289ED77D1D6B9C97C77AFF2DE013699707D17B2100	0

Low Level Analysis

Broken Chain



Database Master Key compromised, so all the other keys fall

Detour Over

Back To ManageEngine

ManageEngine Database

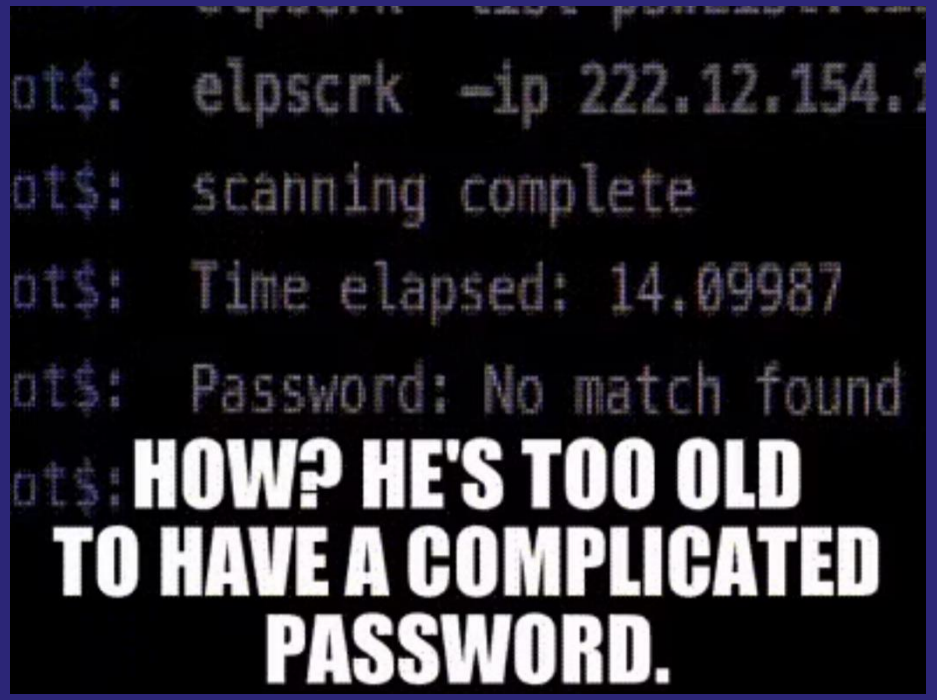
Back to it

- Now that we know how MSSQL crypto works, we can try and bruteforce the key in our original ManageEngine database
- We hoped that it’s ESKP format.. And it was! MD5 cracking is a GO!
- The key hadn’t been rotated in a looooong time, so we were in with a good shot of cracking it!

ManageEngine Database

What's the Craic?

- And it fails to crack ☹
- Experience tells us something is wrong, the password should have cracked!
- So, we have to reverse engineer ManageEngine
- It's Java, so it doesn't take long



ManageEngine Database

What the…?!

- In the config file product-config.xml we see this in our lab deployment:

```
<configuration name="mssql" value="">
        <property name="dbadapter" value="com.adventnet.db.adapter.mssql.MssqlDBAdapter"/>
        <property name="sqlgenerator" value="com.adventnet.db.adapter.mssql.MssqlSQLGenerator"/>
        <sql_function_pattern_file value="conf/Persistence/mssql_functionpatterns.txt"/>
        <property name="masterkey.password" value="23987hxJ#KL95234nl0zBe"/>
</configuration>
```

- Looks random, but we throw that into our password list and… the .bak key CRACKS!

```
Approaching final keyspace - workload adjusted.

4ef7e28054ecb0ae166eac5d73a608e8:1b0f8278:23987hxJ#KL95234nl0zBe

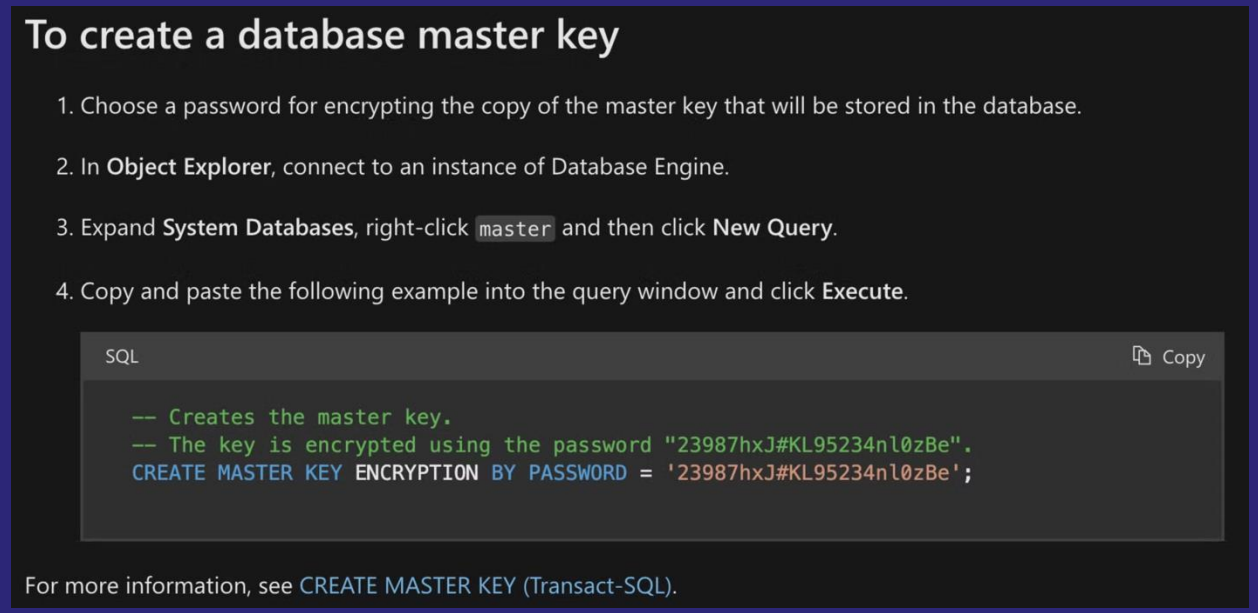
Session..........: hashcat
Status...........: Cracked
```

- How? Is this a hardcoded database master key?

ManageEngine Database

I’ve seen that password before…

- Googling with the password, we find a few hits, including, Microsoft's documentation!



To create a database master key

1. Choose a password for encrypting the copy of the master key that will be stored in the database.
2. In **Object Explorer**, connect to an instance of Database Engine.
3. Expand **System Databases**, right-click `master` and then click **New Query**.
4. Copy and paste the following example into the query window and click **Execute**.

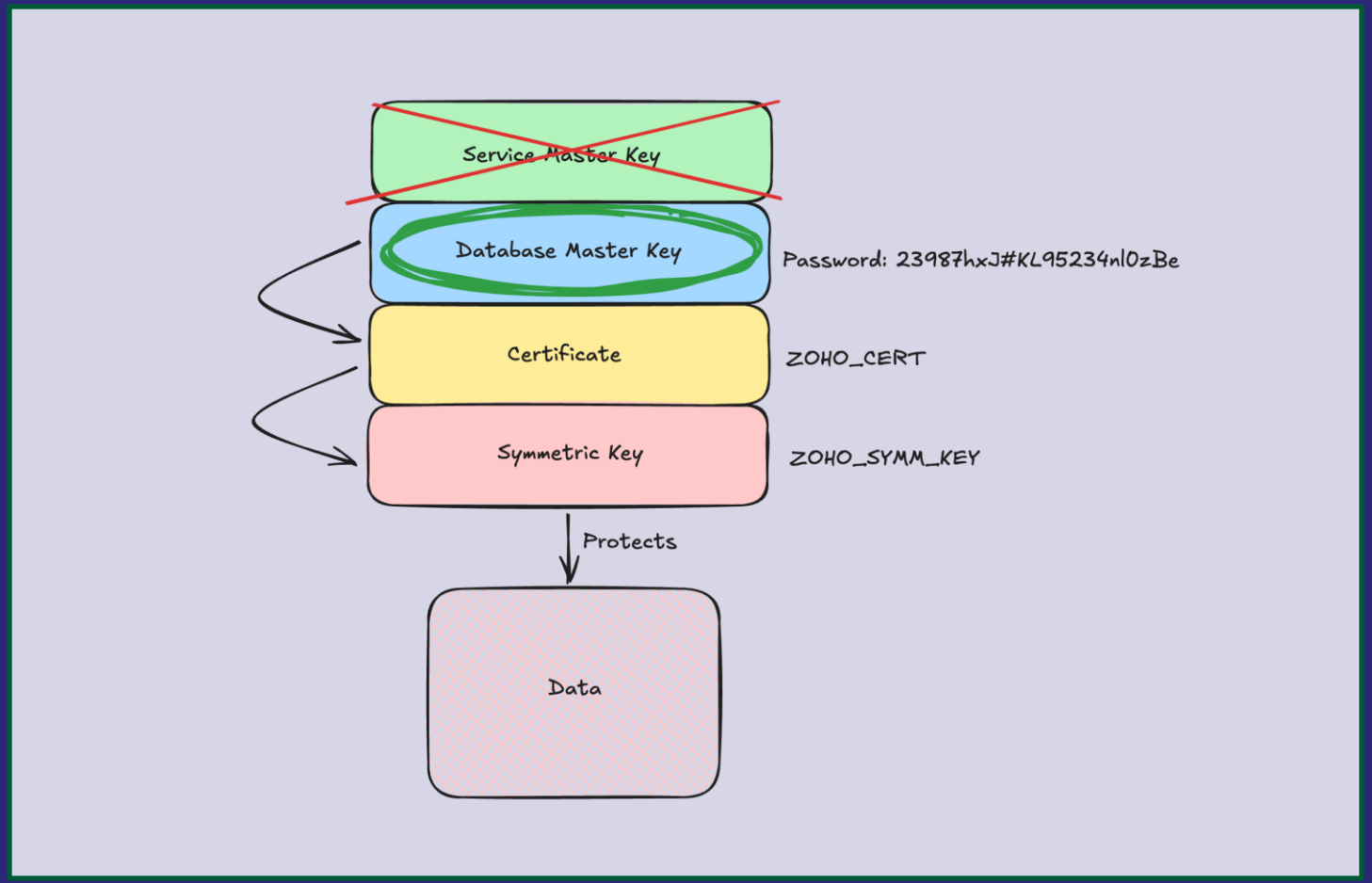
SQL — Copy

```
-- Creates the master key.
-- The key is encrypted using the password "23987hxJ#KL95234nl0zBe".
CREATE MASTER KEY ENCRYPTION BY PASSWORD = '23987hxJ#KL95234nl0zBe';
```

For more information, see CREATE MASTER KEY (Transact-SQL).

ManageEngine Database

The chain falls…



ManageEngine Database

- So, the key to ManageEngine ADSelfService product is.. The stock documentation key from the Microsoft website!
- Hopefully, nothing too important is stored…

- Information fetched from the domain is stored in the product's database (the in-built PostgreSQL or any other database configured externally). During domain configuration, the credentials provided must have Domain Admin privileges or the individual privileges listed out in this guide.

ManageEngine Database

- So, the key to ManageEngine ADSelfService products is.. The stock documentation key from the Microsoft website!
- Hopefully, nothing too important is stored…

```
OPEN MASTER KEY DECRYPTION BY PASSWORD='23987hxJ#KL95234nl0zBe'
OPEN SYMMETRIC KEY ZOHO_SYMM_KEY DECRYPTION BY CERTIFICATE ZOHO_CERT
SELECT CONVERT(NVARCHAR, DECRYPTBYKEY(USER_NAME)), CONVERT(NVARCHAR, DECRYPTBYKEY(PASSWORD)), * FROM ADSMDomainConfiguration
```

100 %

Results | Messages

	(No column name)	(No column name)	DOMAIN_NAME	DOMAIN_DNS_NAME	DOMAIN_FLAT_NAME	DOMAIN_CONTROLLER_ID	USER_NAME
1	itadmin	Pass@word1	lab.local	lab.local	lab	2	0x004F9C0281383874BDF1C828D

Takeaways

- ManageEngine ADSelfService hardcoded password for the DMK is 23987hxJ#KL95234nl0zBe
- If you find a MSSQL .bak which uses encryption, check out the sys.sysobjkeycrypts table and pray for a type of ESKP which is MD5
- Google is your friend.. If you know what to look for ;)

Fixes

- Good password hygiene for database crypto (hopefully this talk shows the “why” which is half the battle sometimes)
- Rotate any ADSelfService encryption keys and product-config.xml
- Closely guard any backups from any RedTeamers who come ‘a snoopin!

SPECTEROPS

Thank you

Any Questions?

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