# SQL Server Database Security Audit

ISACA Denver Chapter
January 2016




# Agenda

- Introduction
- Learning objectives
- Definitions
- SQL Server architecture
- Defaults
- Permissions model
- Security standards
- Authentication
- Performing an audit
- Q&A




# Introduction - Who am I?

- Sr IT Audit Leader - Wells Fargo Audit Services
- Past life …
  - Information system security officer (ISSO)
  - Database and application security engineer
  - Oracle/SQL Server/Sybase DBA and developer
  - C language programmer
    - CP/M
    - MS-DOS
    - VAX/VMS
    - Mac OS 7
    - UNIX

# Caveats

- Always get permission to run any scripts in your environment
- Always test scripts in a non-production environment before using them in production
  - Vet the scripts with your IT DBA team
- The testing methodology is my own
- The scripts used in the presentation are working in a test environment (I also use them in my present position to execute audit testing)




# Learning objectives

- SQL Server architecture
- Data access model for SQL Server
- Understanding of
  - Security containers model
  - Server and database level roles
  - Sweeping security roles
- Database audit trail




# Preliminaries

The big picture

- Database security is all about …
  - Data security and access
- How data is protected by …
  - The installation and configuration of the software
  - Access to the data and log files that contain data through operating system permissions
  - Patching
  - System privileges
  - RBAC application design
  - Direct (and denied) access
  - Auditing and monitoring

# Definitions




# Definition - database instance

- SQL Server is a Windows service which manages a group of databases
  - Disk files
  - Memory
  - Network connections
  - User processes




# Definition - database

- Logical container
- Security boundary

# Definition - principal

- Entities that can request and use resources
- Can be arranged in a hierarchy
  - Windows-level
    - Windows domain login
    - Windows local login
  - SQL Server-level
    - SQL Server login
  - Database-level
    - Database user
    - Database role
    - Application role




# Securables




# Server scope

- Access to resources which SQL Server authorization regulates
  - End point
  - Login
  - Database

# Database scope

- User
- Role
- Application role
- Assembly
- Message type
- Route
- Service
- Remote Service binding
- Fulltext catalog
- Certificate
- Key (asymmetric, symmetric)
- Contract
- Schema




# Schema scope

- Type
- XML Schema Collection
- Object




# Object scope

- Aggregate
- Function
- Procedure
- Queue
- Synonym
- Table
- View

# SQL Server Architecture




# Categories




| Category | Description |
|---|---|
| Database Engine | The Database Engine is the core service for storing, processing and securing data. The Database Engine provides controlled access and rapid transaction processing to meet the requirements of the most demanding data consuming applications within your enterprise. The Database Engine also provides rich support for sustaining high availability. |
| Analysis Services - Multidimensional Data | Analysis Services supports OLAP by allowing you to design, create, and manage multidimensional structures that contain data aggregated from other data sources such as relational databases. |
| Analysis Services - Data Mining | Analysis Services enables you to design, create and visualize data mining models. These mining models can be constructed from other data sources by using a wide variety of industry-standard data mining algorithms. |
| Integration Services | Services is a platform for building high performance data integration solutions including packages that provide extract, transform, and load (ETL) processing for data warehousing. |
| Master Data Services | Master Data Services is the source of master data for your organization. By integrating disparate operational and analytic systems with Master Data Services you ensure that all applications across the organization rely on a central accurate source of information. Using Master Data Services you create a single source of master data and maintain an auditable record of that data as it changes over time. |
| Replication | Replication is a set of technologies for copying and distributing data and database objects from one database to another and then synchronizing between databases to maintain consistency. By using replication you can distribute data to different locations and to remote or mobile users by means of local and wide area networks dial-up connections wireless connections and the Internet. |
| Reporting Services | Reporting Services delivers enterprise Web-enabled reporting functionality so you can create reports that draw content from a variety of data sources publish reports in various formats and centrally manage security and subscriptions. |
| SharePoint Integration | SQL Server 2008 R2 offers new self-service business intelligence capability through integration with SharePoint products and technologies. In this release both Analysis Services and Reporting Services support deployment in a SharePoint farm. |
| Service Broker | Service Broker helps developers build scalable secure database applications. This new Database Engine technology provides a message-based communication platform that enables independent application components to perform as a functioning whole. Service Broker includes infrastructure for asynchronous programming that can be used for applications within a single database or a single instance and also for distributed applications. |

# Database engine components

- Relational engine
- Storage engine
- SQLOS




# Relational engine

- Query processor
- All components to determine resources needed to process queries
  - Query processing
  - Memory management
  - Thread and task management
  - Buffer management
  - Distributed query processing




# Storage engine

- Responsible for storage and retrieval of data to the disk storage system
- Mapped over set of operating system files
- Three types of files
  - Primary data file
  - Secondary data files
  - Log files

# SQLOS

- Interface (API) SQL Server and Windows host operating system
- Query engine and query optimizer abstraction layer
- No special privileges or priority
- Does not bypass Windows OS
  - Memory management
  - Buffer pools
  - Log buffer
  - Deadlock detection
  - Exception handling
  - Common language runtime (CLR)
  - Scheduling




# SQL Server instances

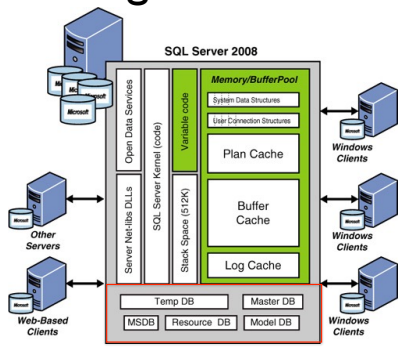
- Two types of SQL Server database engine instances
  - Single instance
  - Clustered instance
- Default instance
- Named instance




# Default vs. named instance

- Default instance
  - One default instance per server
  - Connect by specifying server only; port TCP: 1433
- Named instance
  - Many per server
  - Connect by specifying server and instance (Server\Instance)
  - SQL Browser service identifies and returns the port the named instance listens on

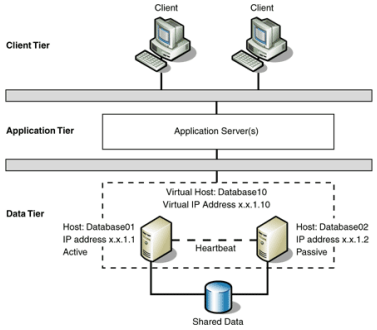
# Single instance







# Clustered instance



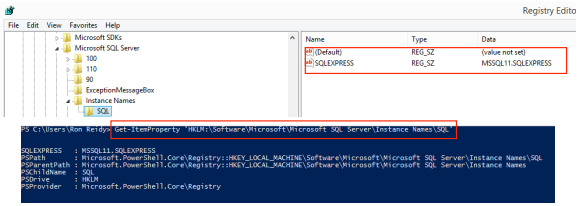




# Installed instances

- Installed instances found in the registry

HKLM\SOFTWARE\Microsoft\Microsoft SQL Server\Instance Names\SQL



# Disk files

- All data in a SQL Server instance is written to data files on disk
- Locations of data files specified in the data dictionary
- Check locations
- Check permissions




# Networking

- Ports & Protocols
- Listening port
- Browser service




# Ports & protocols

- Networking communications are defined by both the port and protocol using the port
- Protocols supported
  - TCP/IP
  - Named Pipes
  - Shared Memory
  - VIA

# Common ports

| Description | Protocol | Port |
|---|---|---|
| Database Engine (default instance) | TCP | 1433 |
| Database Engine (default instance) | UDP | 1434 |
| Database Mail | SMTP | 25 |
| Database Mirroring | TCP | No official default port, but examples tend to use 5022. |
| Dedicated Administrative Connection (default instance) | TCP | 1434 |
| Filestream | TCP | 139 and 445 |
| Service Broker | TCP | No official default port, but examples tend to use 4022. |
| SQL Server Browser Service | UDP/TCP | UDP: 1434<br>TCP: 2382 |
| SQL Server (default instance) over HTTP | TCP | 80 |
| SQL Server (default instance) over HTTPS | TCP | 443 |
| SQL Server Integration Services | TCP | 135 |
| TSQL Debugger | TCP | 135 |




# Listening port

- The port used by client programs to connect to the database engine.
  - Default is TCP:1433
  - Used by the default instance




# Browser service

- Windows service
- Listens for incoming connection requests
  - Provides information about SQL Server instances on the server (instance name and version)

# Defaults




# Logins

- Many accounts created when SQL Server instance created
- sa
  - Server-level principal
- INFORMATION_SCHEMA & sys
  - Appear as users in catalog views
  - Required by SQL Server
  - Not principals
  - Cannot be modified or dropped




# Certificate-based server logins

- Names enclosed in double "#"
- Created from certificates
- Should not be deleted
  - ##MS_SQLResourceSigningCertificate##
  - ##MS_SQLReplicationSigningCertificate##
  - ##MS_SQLAuthenticatorCertificate##
  - ##MS_AgentSigningCertificate##
  - ##MS_PolicyEventProcessingLogin##
  - ##MS_PolicySigningCertificate##
  - ##MS_PolicyTsqlExecutionLogin##

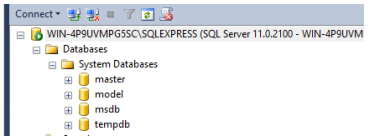
# Service accounts

- Service accounts created during installation
  - Startup accounts used to start and run SQL Server can be domain user accounts, local user accounts, managed service accounts, virtual accounts, or built-in system accounts.
- Others can be created for use by applications




# Databases

- The databases can be seen from SQL Server Management Studio
  - Expand Databases->System Databases







# Default Databases

| System database | Description |
|---|---|
| master Database | Records all the system-level information for an instance of SQL Server. |
| msdb Database | Is used by SQL Server Agent for scheduling alerts and jobs. |
| model Database | Is used as the template for all databases created on the instance of SQL Server. Modifications made to the model database, such as database size, collation, recovery model, and other database options, are applied to any databases created afterward. |
| Resource Database | Is a read-only database that contains system objects that are included with SQL Server. System objects are physically persisted in the Resource database, but they logically appear in the sys schema of every database. |
| tempdb Database | Is a workspace for holding temporary objects or intermediate result sets. |

# Default file locations

- Shared files for all instances
- <*drive*>:\Program Files\Microsoft SQL Server\100\, where <*drive*> is the drive letter where components are installed. The default is drive C.
  - Use of the C:\ drive is not advised and should be avoided.




# Default Event logs

- Log size - 102400 KB
  - Default size = 102400 KB
  - Maximum size = 15168 KB
- Number of logs = 12

**Leading practice - All of these values are too small for a production environment**



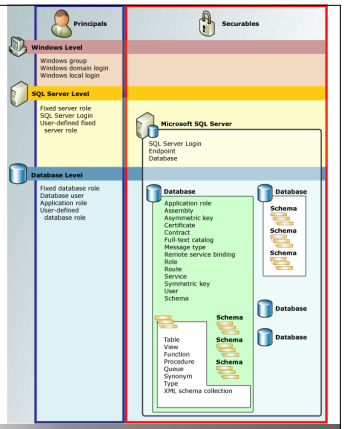

# Permissions model

# Overview

- The permissions model is very granular
- Roles
  - Server-level roles
  - Database-level roles
    - Allow
    - Deny
  - Application roles
- Direct grants
  - Allow
  - Deny




# Permissions relationships







# Server-level roles

- Manage permissions of the server
  - Security principals that group other principals
- Server wide in scope
  - Similar to groups in Windows operating system
- You can add server level principals to server-level roles
  - SQL Server logins
  - Windows accounts
  - Windows groups
- Permissions granted to the server-level roles cannot be changed (fixed)

**Starting in SQL Server 2012, user-defined server roles can be created**

| Server-level role name | Description |
|---|---|
| sysadmin | Members of the sysadmin fixed server role can perform any activity in the server. |
| serveradmin | Members of the serveradmin fixed server role can change server-wide configuration options and shut down the server. |
| securityadmin | Members of the securityadmin fixed server role manage logins and their properties. They can GRANT, DENY, and REVOKE server-level permissions. They can also GRANT, DENY, and REVOKE database-level permissions if they have access to a database. Additionally, they can reset passwords for SQL Server logins. |
| processadmin | Members of the processadmin fixed server role can end processes that are running in an instance of SQL Server. |
| setupadmin | Members of the setupadmin fixed server role can add and remove linked servers. |
| bulkadmin | Members of the bulkadmin fixed server role can run the BULK INSERT statement. |
| diskadmin | The diskadmin fixed server role is used for managing disk files. |
| dbcreator | Members of the dbcreator fixed server role can create, alter, drop, and restore any database. |
| public<br>**NOTE: Implemented differently than other roles.** | Every SQL Server login belongs to the public server role. When a server principal has not been granted or denied specific permissions on a securable object, the user inherits the permissions granted to public on that object. |

Members of the SYSADMIN and SECURITYADMIN roles should be treated as equally powerful.




# Permissions of server-level roles

| Fixed server role | Server-level permission |
|---|---|
| bulkadmin | Granted: ADMINISTER BULK OPERATIONS |
| dbcreator | Granted: CREATE ANY DATABASE |
| diskadmin | Granted: ALTER RESOURCES |
| processadmin | Granted: ALTER ANY CONNECTION, ALTER SERVER STATE |
| securityadmin | Granted: ALTER ANY LOGIN |
| serveradmin | Granted: ALTER ANY ENDPOINT, ALTER RESOURCES, ALTER SERVER STATE, ALTER SETTINGS, SHUTDOWN, VIEW SERVER STATE |
| setupadmin | Granted: ALTER ANY LINKED SERVER |
| sysadmin | Granted with GRANT option: CONTROL SERVER |




# Database-level roles

- Manage permissions of the databases
  - Security principals that group other principals
- Database wide in scope and exist in each database
- Any database account and any server role can be added into database-level roles
- Any member of a database-level role can add other logins to that same role
- Three different types of roles
  - Administration roles
  - Data access roles
  - Roles restricted to the msdb database

Database roles should **never** be members of fixed roles. This could enable unintended privilege escalation.

# Administration roles

| Database-level role name | Description |
|---|---|
| db_owner | Members of the **db_owner** fixed database role can perform all configuration and maintenance activities on the database, and can also drop the database. |
| db_securityadmin | Members of the **db_securityadmin** fixed database role can modify role membership and manage permissions. **Adding principals to this role could enable unintended privilege escalation.** |
| db_accessadmin | Members of the **db_accessadmin** fixed database role can add or remove access to the database for Windows logins, Windows groups, and SQL Server logins. |
| db_backupoperator | Members of the **db_backupoperator** fixed database role can back up the database. |
| db_ddladmin | Members of the **db_ddladmin** fixed database role can run any Data Definition Language (DDL) command in a database. |




# Data access roles

| Database-level role name | Description |
|---|---|
| db_datawriter | Members of the **db_datawriter** fixed database role **can** add, delete, or change data in all user tables. |
| db_datareader | Members of the **db_datareader** fixed database role **can** read all data from all user tables. |
| db_denydatawriter | Members of the **db_denydatawriter** fixed database role **cannot** add, modify, or delete any data in the user tables within a database. |
| db_denydatareader | Members of the **db_denydatareader** fixed database role **cannot** read any data in the user tables within a database. |




# msdb specific roles

| msdb role name | Description |
|---|---|
| db_ssisadmin<br>db_ssisoperator<br>db_ssisltduser | Members of these database roles can administer and use SSIS. |
| dc_admin<br>dc_operator<br>dc_proxy | Members of the **db_datareader** fixed database role can read all data from all user tables. |
| PolicyAdministratorRole | Members of the **db_ PolicyAdministratorRole** database role can perform all configuration and maintenance activities on Policy-Based Management policies and conditions. |
| ServerGroupAdministratorRole<br>ServerGroupReaderRole | Members of these database roles can administer and use registered server groups. |
| dbm_monitor | Created in the **msdb** database when the first database is registered in Database Mirroring Monitor. |

Members of the db_ssisadmin role and the dc_admin role may be able to elevate their privileges to sysadmin. This elevation of privilege can occur because these roles can modify Integration Services packages and Integration Services packages can be executed by SQL Server using the sysadmin security context of SQL Server Agent.

# PUBLIC

- All principals belong to the database role PUBLIC
  - When a user has not been granted or denied specific permissions on a securable object, the user inherits the permissions granted to **public** on that object.




# High risk system privileges

- All server-level roles are granted specific (fixed) privileges
- Many other high risk privileges

| Permission Name | Permission State | Principal Name | Principal Type | Principal Is Disabled |
|---|---|---|---|---|
| ALTER ANY AVAILABILITY GROUP | GRANT | NT AUTHORITY\SYSTEM | WINDOWS_LOGIN | FALSE |
| CONNECT SQL | GRANT | BUILTIN\Users | WINDOWS_GROUP | FALSE |
| CONNECT SQL | GRANT | NT AUTHORITY\SYSTEM | WINDOWS_LOGIN | FALSE |
| CONNECT SQL | GRANT | NT Service\MSSQL$SQLEXPRESS | WINDOWS_LOGIN | FALSE |
| CONNECT SQL | GRANT | NT SERVICE\SQLWriter | WINDOWS_LOGIN | FALSE |
| CONNECT SQL | GRANT | NT SERVICE\Winmgmt | WINDOWS_LOGIN | FALSE |
| CONNECT SQL | GRANT | sa | SQL_LOGIN | TRUE |
| CONNECT SQL | GRANT | WIN-4P9UVMPG5SC\Ron Reidy | WINDOWS_LOGIN | FALSE |
| VIEW SERVER STATE | GRANT | NT AUTHORITY\SYSTEM | WINDOWS_LOGIN | FALSE |




# Application roles

- Allows application to run with user-like permissions
- Enable access to specific data
  - Contain no members
  - Inactive by default
  - Access other databases through permissions granted in those databases to the guest account
- Not associated with server-level principals

# User-defined roles

- Database-level securable
- Can be assigned an AUTHORIZATION
  - Database user or role that owns the role
  - Default is the user that creates the role
- Requires CREATE ROLE or the DB_SECURITYADMIN database-level role
  - To assign to another user requires IMPERSONATE permission on that user
  - To assign to another role requires ALTER permission on that role
  - To assign to an application role requires ALTER permission on the application role




# Direct grants - Allow

- Grants permissions on a table, view, table-valued function, stored procedure, extended stored procedure, scalar function, aggregate function, service queue, or synonym
  - Tables/views (INSERT, UPDATE, DELETE, SELECT, REFERENCES, etc.)
  - Stored procedures (EXECUTE)
- WITH GRANT OPTION
  - Principal may grant the privilege to other principals




# Direct grants - Deny

- Denies permissions on a member of the OBJECT class of securables. These are the members of the OBJECT class: tables, views, table-valued functions, stored procedures, extended stored procedures, scalar functions, aggregate functions, service queues, and synonyms.
- DENY takes precedence over grant
  - Exception - table-level DENY does not take precedence over column-level GRANT

# Security standards




# Security standard

- Something considered by an authority or by general consent as a basis of comparison; an approved model.
- Base security stance
- Most organizations have technical standards




# Free security benchmarks

- CIS SQL Server Benchmark
  http://benchmarks.cisecurity.org/downloads/browse/index.cfm?category=benchmarks.servers.database.mssql
- DISA STIG
  http://iase.disa.mil/stigs/app-security/database/Pages/sql.aspx
- Microsoft
  http://blogs.technet.com/b/secguide/archive/2014/03/24/sql-server-2012-baselines-are-now-live.aspx

# Vendor tools

- CIS
- Tenable Nessus
- Trustwave AppDetective Pro
- Microsoft SQLRAP




# Authentication




# Modes

- Windows authentication (local accounts and Active Directory managed accounts)
- SQL Server authentication

# Windows authentication

- Account name and password validated using the Windows principal token (OS layer)
- Identity confirmed by the OS
  - Default mode
  - Uses Kerberos
    - Password policy enforcement
    - Account lockout
    - Password expiration
- Windows groups can be used at the domain level
  - Logins added to the group
  - Simplified administration

Preferred method and leading practice




# SQL Server authentication

- Logins **NOT** based on Windows logins
- Username and password are created and stored in SQL Server
  - Strong passwords must be set for all accounts

'sa' must always have a password

| name | is_security_policy_checked | is_expiration_checked | is_disabled |
|---|---|---|---|
| sa | TRUE | FALSE | TRUE |
| ##MS_PolicyEventProcessingLogin## | TRUE | FALSE | TRUE |
| ##MS_PolicyTsqlExecutionLogin## | TRUE | FALSE | TRUE |




# SQL Server password policies

- User must change password at next login

Requires the user to change the password the next time that the user connects. The ability to change the password is provided by SQL Server Management Studio.

- Enforce password expiration

The maximum password age policy of the computer is enforced for SQL Server logins.

- Enforce password complexity

The Windows password policies of the computer are enforced for SQL Server logins. This includes password length and complexity.

# Advantages

- Allows SQL Server to support older applications and applications provided by third parties that require SQL Server Authentication.
- Allows SQL Server to support environments with mixed operating systems, where all users are not authenticated by a Windows domain.
- Allows users to connect from unknown or untrusted domains.
- Allows SQL Server to support Web-based applications where users create their own identities.
- Allows software developers to distribute their applications by using a complex permission hierarchy based on known, preset SQL Server logins.




# Disadvantages

- If a user is a Windows domain user who has a login and password for Windows, he must still provide another (SQL Server) login and password to connect. Keeping track of multiple names and passwords is difficult for many users.
- SQL Server Authentication cannot use Kerberos security protocol.
- Windows offers additional password policies that are not available for SQL Server logins.
- The encrypted SQL Server Authentication login password, must be passed over the network at the time of the connection. Some applications that connect automatically will store the password at the client. These are additional attack points.

**Using SQL Server Authentication does not limit the permissions of local administrators on the computer where SQL Server is installed.**




# Performing the audit

# Audit types - management

- Software installation
- Roles
- Administration
- Security configurations
- Configuration management
- Application audit




# Software installation



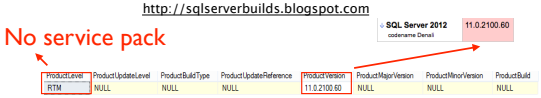

# Dedicated server

- SQL Server should be in a dedicated server
  - Never on a domain controller
  - Never with a web server
  - No security software
  - No email server
  - etc.

# Version and service pack information

- Ensure SQL Server is a current supported version.

http://sqlserverbuilds.blogspot.com

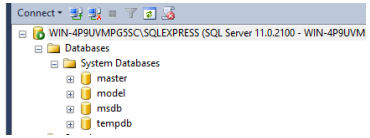






# List databases

- The databases can be seen from SQL Server Management Studio
  - Expand Databases->System Databases







# List databases

- The databases can be obtained from the database data dictionary

| | name | database_id | create_date |
|---|---|---|---|
| 1 | master | 1 | 2003-04-08 09:13:36.390 |
| 2 | tempdb | 2 | 2015-11-12 05:06:39.440 |
| 3 | model | 3 | 2003-04-08 09:13:36.390 |
| 4 | msdb | 4 | 2012-02-10 21:02:17.770 |

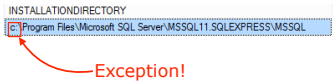
As with management studio, the Resource DB is hidden.

# Location of software

- Should not be on the system partition

```
PS C:\> $env:systemdrive
C:
```

- Location is the registry
  HKLM\SOFTWARE\Microsoft SQL Server\MSSQL11.<instance name>\Setup





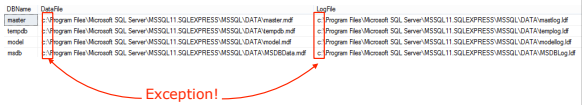


# Location of data files

- Data directories must not be on the system partition

```
PS C:\Users\Ron Reidy> $env:systemdrive
C:
```

- Data files

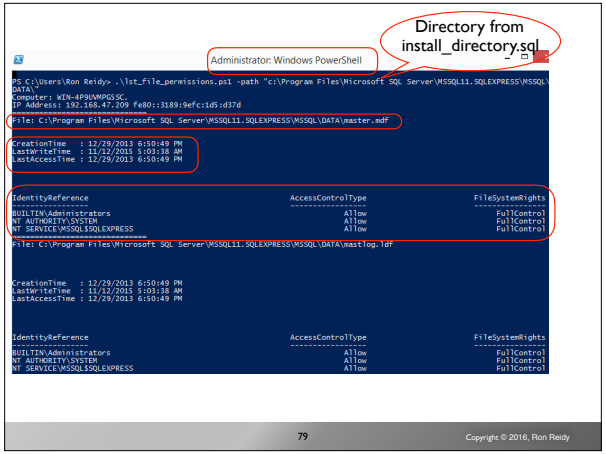






# OS Permissions to database files

- Data files can contain sensitive application data as well as password hashes for SQL logins
- Log files contain transaction information
- Test permissions on all folders containing data or log files
- Validate access is appropriate





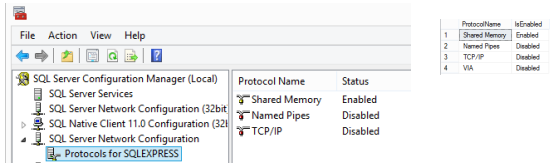


# Networking




# Enabled network protocols

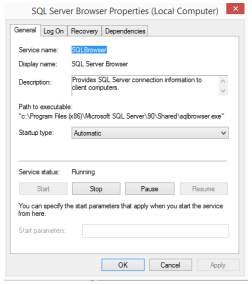
- Identify all SQL Server networking protocols enabled

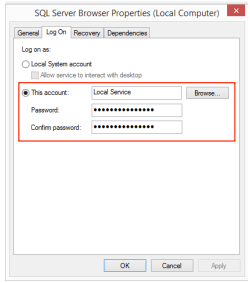


# Browser service

- Windows service
- Listens for incoming connection requests
  - Provides information about SQL Server instances on the server (instance name and version)



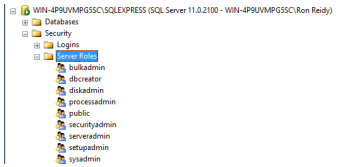

```
PS C:\Users\Ron Reidy> get-service -name SQLBrowser | Format-List

Name                  : SQLBrowser
DisplayName           : SQL Server Browser
Status                : Running
DependentServices     : {}
ServicesDependedOn    : {}
CanPauseAndContinue   : True
CanShutdown           : True
CanStop               : True
ServiceType           : Win32OwnProcess
```




# Roles

## List all server-level roles







## Identify accounts with server-level roles

| SERVERNAME | LOGINNAME | SYSADMIN | SECURITYADMIN | SETUPADMIN | PROCESSADMIN | DISKADMIN | DBCREATOR | BULKADMIN |
|---|---|---|---|---|---|---|---|---|
| Server1\PROD_DB | [redacted]\Prod_DBA | TRUE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE |
| Server1\PROD_DB | [redacted]\Auditors | FALSE | FALSE | TRUE | FALSE | FALSE | FALSE | FALSE |
| Server1\PROD_DB | [redacted]\Dev_DBA | FALSE | FALSE | FALSE | FALSE | FALSE | TRUE | FALSE |
| Server1\PROD_DB | [redacted]\Windows_Admins | TRUE | FALSE | FALSE | FALSE | FALSE | TRUE | FALSE |
| Server1\PROD_DB | [redacted]\Windows_Admins_NonPriv | TRUE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE |




## List all database-level roles

```
1  exec sp_helpdbfixedrole;
```

100 %

Results | Messages

| | DbFixedRole | Description |
|---|---|---|
| 1 | db_owner | DB Owners |
| 2 | db_accessadmin | DB Access Administrators |
| 3 | db_securityadmin | DB Security Administrators |
| 4 | db_ddladmin | DB DDL Administrators |
| 5 | db_backupoperator | DB Backup Operator |
| 6 | db_datareader | DB Data Reader |
| 7 | db_datawriter | DB Data Writer |
| 8 | db_denydatareader | DB Deny Data Reader |
| 9 | db_denydatawriter | DB Deny Data Writer |

# Identify accounts with database-level roles

| SERVERNAME | DBNAME | USERNAME | DB_OWNER | DB_ACCESSADMIN | DB_SECURITYADMIN | DB_DDLADMIN | DB_DATAREADER | DB_DATAWRITER | DB_DENYDATAREADER | DB_DENYDATAWRIT |
|---|---|---|---|---|---|---|---|---|---|---|
| Server1\PROD_DB | Fin | dbo | TRUE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE |
| Server1\PROD_DB | Purch | [redacted]_Prod_DBA | FALSE | FALSE | TRUE | TRUE | TRUE | TRUE | FALSE | FALSE |
| Server1\PROD_DB | HR | [redacted]Dev_DBA | FALSE | FALSE | FALSE | FALSE | TRUE | TRUE | FALSE | FALSE |
| Server1\PROD_DB | Stage | [redacted]_Prod_DBA | FALSE | FALSE | FALSE | TRUE | TRUE | TRUE | FALSE | FALSE |
| Server1\PROD_DB | WH1 | Bob | FALSE | FALSE | FALSE | FALSE | **FALSE** | **FALSE** | TRUE | TRUE |
| Server1\PROD_DB | WH2 | [redacted]_Windows_Admins | FALSE | FALSE | FALSE | TRUE | TRUE | TRUE | FALSE | FALSE |
| Server1\PROD_DB | WH1 | [redacted]_Windows_Admin_NonPriv | FALSE | FALSE | FALSE | FALSE | TRUE | FALSE | FALSE | FALSE |

Overrides DB_DATAREADER and DB_DATAWRITER




# Administration




# Windows OS administrative accounts

- Windows-authenticated accounts that have administrative access to the SQL Server
  - Windows built-in accounts
  - Local Windows groups
  - Active Directory groups
- Password trust obtained from the operating system

# Identify all OS groups and accounts

- Verify they are authorized administrators

```
PS C:\Users\Ron Reidy> Get-WmiObject win32_groupuser |
>> Where-Object { $_.GroupComponent -match 'administrators' } |
>> ForEach-Object {[wmi]$_.PartComponent } | export-csv admins.csv
>>
PS C:\Users\Ron Reidy>
```

```
1 #TYPE System.Management.ManagementObject#root\cimv2\Win32_UserAccount
2 PSComputerName  __GENUS  __CLASS  __SUPERCLASS  __DYNAST  __RELPATH
3 WIN-4P9UVMPGS5C  2  Win32_Us  Win32_Account  CIM_Mana  Win32_UserAccount.Domain="WIN-4P9UVMPGS5C",Name="Administrator"
4 WIN-4P9UVMPGS5C  2  Win32_Us  Win32_Account  CIM_Mana  Win32_UserAccount.Domain="WIN-4P9UVMPGS5C",Name="Ron Reidy"
```




# Service accounts

- Valid service accounts
  - Local user
  - Domain user
  - NetworkService
  - Local System

```
WIN-4P9UVMPGS5C  name                  state    startname
---------------  ----                  -----    ---------
                 MSSQL$SQLEXPRESS      Running  NT Service\MSSQL$SQLEXPRESS
                 SQLAgent$SQLEXPRESS   Stopped  NT AUTHORITY\NETWORKSERVICE
                 SQLBrowser            Running  NT AUTHORITY\LOCALSERVICE
                 SQLWriter             Running  LocalSystem
```




# Administrative logins

- Ensure all administrative SQL logins have password settings enabled

| name | Access_Method | is_expiration_checked | is_security_policy_checked | is_disabled |
|---|---|---|---|---|
| sa | sysadmin membership | FALSE | TRUE | TRUE |
| sa | serveradmin membership | FALSE | TRUE | TRUE |
| sa | securityadmin membership | FALSE | TRUE | TRUE |

# Built-in users

- Local windows group (BUILTIN\Users)
  - Run applications
  - Use printers
  - Shutdown and lock computer
- All accounts on server are members of this group

| LoginName | type_desc | is_disabled | db_perms | srv_perms |
|---|---|---|---|---|
| BUILTIN\Users | WINDOWS_GROUP | FALSE | no_db_users | no_srv_permissions |




# Built-in administrators

- Full control over the windows server
- Access should be limited (after installation, only "Administrator" is present)

| server_name | SrvRole | LoginName |
|---|---|---|

Leading practice - the Administrators group should not have access to SQL Server.




# Security configurations

# Server configuration

- Stored in the data dictionary
- Can be modified

| name | value_configured | value_in_use | description |
|---|---|---|---|
| Ad Hoc Distributed Queries | FALSE | FALSE | Enable or disable Ad Hoc Distributed Queries |
| c2 audit mode | FALSE | FALSE | c2 audit mode |
| clr enabled | FALSE | FALSE | CLR user code execution enabled in the server |
| contained database authentication | FALSE | FALSE | Enables contained databases and contained authentication |
| cross db ownership chaining | FALSE | FALSE | Allow cross db ownership chaining |
| Database Mail XPs | FALSE | FALSE | Enable or disable Database Mail XPs |
| default trace enabled | TRUE | TRUE | Enable or disable the default trace |
| filestream access level | FALSE | FALSE | Sets the FILESTREAM access level |
| Ole Automation Procedures | FALSE | FALSE | Enable or disable Ole Automation Procedures |
| remote access | TRUE | TRUE | Allow remote access |
| remote admin connections | FALSE | FALSE | Dedicated Admin Connections are allowed from remote clients |
| remote login timeout (s) | TRUE | TRUE | remote login timeout |
| scan for startup procs | FALSE | FALSE | scan for startup stored procedures |
| show advanced options | FALSE | TRUE | show advanced options |
| SMO and DMO XPs | TRUE | TRUE | Enable or disable SMO and DMO XPs |
| user instance timeout | TRUE | TRUE | The timeout of the user instance after no connection is made on the server |
| xp_cmdshell | FALSE | FALSE | Enable or disable command shell |




# CLR enabled

- If enabled, identify all CLR assemblies stored in the DB instance and validate them

| db | owner | name | clr_name | permission_set_desc | is_visible | create_date | modify_date | is_user_defined |
|---|---|---|---|---|---|---|---|---|
| master | securityadmin | microsoft.sqlserver.types, version=11.0.0.0, cul... | Microsoft.SqlServer.Types | UNSAFE_ACCESS | TRUE | 2012-02-10 20:15:58.843 | 2012-02-10 20:15:59.427 | FALSE |
| tempdb | securityadmin | microsoft.sqlserver.types, version=11.0.0.0, cul... | Microsoft.SqlServer.Types | UNSAFE_ACCESS | TRUE | 2012-02-10 20:15:58.843 | 2012-02-10 20:15:59.427 | FALSE |
| model | securityadmin | microsoft.sqlserver.types, version=11.0.0.0, cul... | Microsoft.SqlServer.Types | UNSAFE_ACCESS | TRUE | 2012-02-10 20:15:58.843 | 2012-02-10 20:15:59.427 | FALSE |
| msdb | securityadmin | microsoft.sqlserver.types, version=11.0.0.0, cul... | Microsoft.SqlServer.Types | UNSAFE_ACCESS | TRUE | 2012-02-10 20:15:58.843 | 2012-02-10 20:15:59.427 | FALSE |




# Scan for startup procs

- Stored procedures that execute when SQL Server starts

| name | minimum | maximum | config_value | run_value |
|---|---|---|---|---|
| scan for startup procs | 0 | 1 | 0 | 0 |

- If enabled, validate it should be enabled
- Validate any startup proc found are authorized to run

# A note about the trustworthy bit

- The Trustworthy bit allows database objects to access objects in other (remote) databases
- Setting this to 'off' provides protection from malicious CLR assemblies or extended procedures
- The exception to this is the 'sa' account




# A note about the trustworthy bit

If the database owner for a database is assigned to the SYSADMIN server role and the database has its TRUSTWORTHY bit set to ON then a privileged database user can elevate privileges to the SYSADMIN server role and compromise the system. MSDB database is allowed to have the database owner assigned to the SYSADMIN server role and TRUSTWORTHY bit set to ON.

- The exception to this is the 'sa' account

| DATABASE_NAME | OWNER_LOGIN | is_trustwothy_on | EXCEPTION |
|---|---|---|---|
| master | sa | FALSE | FALSE |
| tempdb | sa | FALSE | FALSE |
| model | sa | FALSE | FALSE |
| msdb | sa | TRUE | FALSE |




# Stored procedures

- SQL Server has many built-in stored procedures.
- CIS benchmark specifies only 'xp_cmdshell'
- Many others included which are not controlled by configuration system
  - Access given to PUBLIC

# Stored procedures

| Stored procedure | Description |
|---|---|
| xp_dirtree | Used to get a list of all the folders for the folder named in the xp |
| xp_fileexist | Determine whether a particular file exists on the disk or not |
| xp_fixeddrives | Returns the list of all hard drives and the amount of free space in Mb for each hard drive. |
| xp_getnetname | Returns the WINS name of the SQL Server that you're connected to |
| xp_instance_regread | Reads the registry |
| xp_msver | Returns version information about Microsoft SQL Server. **xp_msver** also returns information about the actual build number of the server and information about the server environment. |
| xp_qv | Returns information about the SKU type, licensing etc. |
| xp_regread | Reads the registry |
| xp_replposteor | Replication |
| xp_sprintf | Formats and stores a series of characters and values in the string output parameter. |
| xp_sscanf | Reads data from the string into the argument locations specified by each format argument. |




# Configuration management

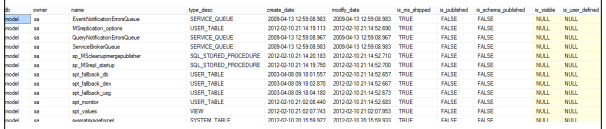



# Database objects

- Objects in the database can be changed by owners of the objects
  - Logins and accounts that can impersonate the owner
  - Server-level roles (sysadmin)
  - Built-in "sa" account
  - The "dbo" of the database (more later)
  - Accounts with database-level DB_OWNER (if not explicitly denied)

# Configuration management

- Identify changed stored procedures, views, and CLR assemblies



| db | owner | name | type_desc | create_date | modify_date | is_ms_shipped | is_published | is_schema_published | is_visible | is_user_defined |
|---|---|---|---|---|---|---|---|---|---|---|
| model | sa | EventNotificationErrorsQueue | SERVICE_QUEUE | 2009-04-13 12:59:08.583 | 2009-04-13 12:59:08.583 | TRUE | FALSE | FALSE | NULL | NULL |
| model | sa | MSreplication_options | USER_TABLE | 2012-02-10 21:14:19.113 | 2012-02-10 21:14:52.630 | TRUE | FALSE | FALSE | NULL | NULL |
| model | sa | QueryNotificationErrorsQueue | SERVICE_QUEUE | 2009-04-13 12:59:08.967 | 2009-04-13 12:59:08.967 | TRUE | FALSE | FALSE | NULL | NULL |
| model | sa | ServiceBrokerQueue | SERVICE_QUEUE | 2009-04-13 12:59:08.583 | 2009-04-13 12:59:08.583 | TRUE | FALSE | FALSE | NULL | NULL |
| model | sa | sp_MSclearsummarypublisher | SQL_STORED_PROCEDURE | 2012-02-10 21:14:20.183 | 2012-02-10 21:14:52.710 | TRUE | FALSE | FALSE | NULL | NULL |
| model | sa | sp_MSreal_startup | SQL_STORED_PROCEDURE | 2012-02-10 21:14:19.750 | 2012-02-10 21:14:52.700 | TRUE | FALSE | FALSE | NULL | NULL |
| model | sa | spt_fallback_db | USER_TABLE | 2003-04-08 09:18:01.557 | 2012-02-10 21:14:52.657 | TRUE | FALSE | FALSE | NULL | NULL |
| model | sa | spt_fallback_dev | USER_TABLE | 2003-04-08 09:18:02.870 | 2012-02-10 21:14:52.667 | TRUE | FALSE | FALSE | NULL | NULL |
| model | sa | spt_fallback_usg | USER_TABLE | 2003-04-08 09:18:04.180 | 2012-02-10 21:14:52.673 | TRUE | FALSE | FALSE | NULL | NULL |
| model | sa | spt_monitor | USER_TABLE | 2012-02-10 21:02:08.440 | 2012-02-10 21:14:52.683 | TRUE | FALSE | FALSE | NULL | NULL |
| model | sa | spt_values | VIEW | 2012-02-10 21:02:07.743 | 2012-02-10 21:02:07.953 | TRUE | FALSE | FALSE | NULL | NULL |
| model | sa | sysutility_ucp_mdw | SYSTEM_TABLE | 2012-02-10 20:15:59.927 | 2012-02-10 20:15:59.933 | TRUE | FALSE | FALSE | NULL | NULL |

- Validate changes were approved




# Application audit

- Roles
- Account management
- Data access




# Roles

- Server level - already covered
- Database level - already covered
- Application

# Application roles

- Database principal allows application to run with user-like permissions
  - Access other databases through permissions granted in those databases to the 'guest' account (if guest is disabled - no access)
- Use to enable access to data and objects
- Contain no members and inactive (by default)
- Enabled by calling 'sp_setapprole' (requires a password)
- Cannot access server-level metadata (not associates with server-level principals
  - Can be set using the 'dbcc traceon' command (global flag 4616)




# Listing all trace events

- dbcc - database console command
- 4 categories of commands

| Command category | Perform |
|---|---|
| Maintenance | Maintenance tasks on a database, index, or filegroup. |
| Miscellaneous | Miscellaneous tasks such as enabling trace flags or removing a DLL from memory. |
| Informational | Tasks that gather and display various types of information. |
| Validation | Validation operations on a database, table, index, catalog, filegroup, or allocation of database pages. |




# tracestatus

```
dbcc tracestatus
```

Results | Messages

| TraceFlag | Status | Global | Session |
|---|---|---|---|
| 8017 | 1 | 1 | 0 |

# List application roles

```
select *
from sys.fn_builtin_permissions(N'APPLICATION ROLE');
```

Results | Messages

| class_desc | permission_name | type | covering_permission_name |
|---|---|---|---|
| APPLICATION ROLE | VIEW DEFINITION | VW | CONTROL |
| APPLICATION ROLE | ALTER | AL | CONTROL |
| APPLICATION ROLE | CONTROL | CL | |




# Account management

- Account analysis
  - Identify accounts and their roles
    - Server and database level




# Identify all accounts with server or database level roles

- SQL logins
- Windows accounts
  - Windows and Active Directory groups

# Server level roles

| SERVERNAME | LOGINNAME | SYSADMIN | SECURITYADMIN | SETUPADMIN | PROCESSADMIN | DISKADMIN | DBCREATOR | BULKADMIN |
|---|---|---|---|---|---|---|---|---|
| Server1\PROD_DB | [redacted]\Prod_DBA | TRUE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE |
| Server1\PROD_DB | [redacted]\Auditors | FALSE | FALSE | TRUE | FALSE | FALSE | FALSE | FALSE |
| Server1\PROD_DB | [redacted]\Dev_DBA | FALSE | FALSE | FALSE | FALSE | FALSE | TRUE | FALSE |
| Server1\PROD_DB | [redacted]\Windows_Admins | TRUE | FALSE | FALSE | FALSE | FALSE | TRUE | FALSE |
| Server1\PROD_DB | [redacted]\Windows_Admins_NonPriv | TRUE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE |




# Database-level roles

| SERVERNAME | DBNAME | USERNAME | DB_OWNER | DB_ACCESSADMIN | DB_SECURITYADMIN | DB_DDLADMIN | DB_DATAREADER | DB_DATAWRITER | DB_DENYDATAREADER | DB_DENYDATAWRIT |
|---|---|---|---|---|---|---|---|---|---|---|
| Server1\PROD_DB | Fin | dbo | TRUE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE |
| Server1\PROD_DB | Purch | [redacted]\Prod_DBA | FALSE | FALSE | TRUE | TRUE | TRUE | TRUE | FALSE | FALSE |
| Server1\PROD_DB | HR | [redacted]\Dev_DBA | FALSE | FALSE | FALSE | FALSE | TRUE | TRUE | FALSE | FALSE |
| Server1\PROD_DB | Stage | [redacted]\Prod_DBA | FALSE | FALSE | FALSE | TRUE | TRUE | TRUE | FALSE | FALSE |
| Server1\PROD_DB | WH1 | Ron | FALSE | FALSE | FALSE | FALSE | **FALSE** | **FALSE** | TRUE | TRUE |
| Server1\PROD_DB | WH2 | [redacted]\Windows_Admins | FALSE | FALSE | FALSE | TRUE | TRUE | TRUE | FALSE | FALSE |
| Server1\PROD_DB | WH1 | [redacted]\Windows_Admin_NonPriv | FALSE | FALSE | FALSE | FALSE | TRUE | FALSE | FALSE | FALSE |

Overrides DB_DATAREADER and DB_DATAWRITER




# dbo

# DB_OWNER database-level role vs. "dbo" account

- "dbo" is a special "pseudo" user in every database
  - **NOT** the same as DB_OWNER database-level role
  - Any account can be assigned the DB_OWNER database-level role
    - Has **complete** control of the database instance and all databases in it
  - All members of the server-level role SYSADMIN are mapped to "dbo"
    - SYSADMINs have **all** rights in **all** databases
  - "dbo" bypasses **all** permissions checks within the database
- Members of the DB_OWNER database-level role but **not** the "dbo" can be DENYied permissions to securables




# dbo

| db | principal_name |
|---|---|
| master | dbo |
| tempdb | dbo |
| model | dbo |
| msdb | dbo |
| AdventureWorks2012 | dbo |

| LoginName | LoginType | SysAdmin |
|---|---|---|
| sa | SQL_LOGIN | TRUE |
| WIN-4P9UVMPG5SC\Ron Reidy | WINDOWS_LOGIN | TRUE |
| NT SERVICE\SQLWriter | WINDOWS_LOGIN | TRUE |
| NT SERVICE\Winmgmt | WINDOWS_LOGIN | TRUE |
| NT Service\MSSQL$SQLEXPRESS | WINDOWS_LOGIN | TRUE |

| db | principal_name | db_account |
|---|---|---|
| master | dbo | sa |
| tempdb | dbo | sa |
| model | dbo | sa |
| msdb | dbo | sa |
| AdventureWorks2012 | dbo | sa |

All are "dbo"




# Data access

# Object names

- Objects names are fully qualified by specifying the "containers" they reside in
- Fully qualified names consist of
  - Server name
  - Database name
  - Schema name
  - Object name
- Specified as *server.database.schema.object*
  - Remote server/database access




# How object permissions are checked

- Object access tested in reverse order of fully qualified name
  - Access granted or denied directly to the object
  - Access granted or denied on the schema containing the object
  - Access granted or denied on the database containing the schema
  - Access granted or denied on the server containing the database
- During these tests, DENY permissions are checked first and access is denied if it exists at ANY of these levels
- If no specific permissions exist, access is denied




# Implicit object access

- There are several ways an object can be accessed implicitly
  - Access given to server-level roles
    - public
    - SYSADMIN
  - Access given to the database-level roles
    - db_datareader - read (SELECT) access to all user tables
      - db_denydatareader denies SELECT
    - db_datawriter - INSERT, UPDATE, DELETE access to all user tables
      - db_denydatawriter denies INSERT, UPDATE, DELETE
    - db_owner - access to all user objects
    - dbo - owns the entire database
  - SQL logins with administrative access (sa and custom logins)

# Access

- Access granted
  - Directly to the principal
  - Through a role (RBAC)




# Permissions

| Object permission | Description |
|---|---|
| ALTER | Change the properties, except ownership, of a particular securable |
| CONTROL | Confers ownership–like capabilities on the grantee. The grantee effectively has all defined permissions on the securable. |
| DELETE | Delete existing rows from a table |
| EXECUTE | Execute a stored procedure or CLR assembly |
| INSERT | Insert new rows into a table |
| REFERENCES | Create a FOREIGN KEY constraint that references that table. |
| SELECT | Select data from a table |
| UPDATE | Update existing rows in a table |




# PUBLIC role

- Server-level role (and database-level role)
  - All principals are members of the PUBLIC role
  - Access to PUBLIC cannot be revoked or denied
  - The PUBLIC role cannot be dropped

# Access given to PUBLIC role

- Many built-in objects granted to PUBLIC
- Many user-defined objects can have access granted to PUBLIC
  - Stored procedures
  - CLR assemblies
  - Tables, views, etc.

| db | name | type_desc | grantor | grantee |
|---|---|---|---|---|
| master | all_columns | VIEW | sa | public |
| master | all_objects | VIEW | sa | public |
| master | all_parameters | VIEW | sa | public |
| master | all_sql_modules | VIEW | sa | public |
| master | all_views | VIEW | sa | public |
| master | allocation_units | VIEW | sa | public |
| master | assemblies | VIEW | sa | public |
| master | assembly_files | VIEW | sa | public |
| master | assembly_modules | VIEW | sa | public |
| master | assembly_references | VIEW | sa | public |
| master | assembly_types | VIEW | sa | public |
| master | asymmetric_keys | VIEW | sa | public |

Object access should be granted to PUBLIC when the need is fully demonstrated




# All endpoints will be granted to PUBLIC

| class_desc | permission_name | state_desc | grantor | name | protocol_desc | ip_address | type_desc | state_desc | is_admin_endpoint | is_dynamic_port |
|---|---|---|---|---|---|---|---|---|---|---|
| SERVER | VIEW ANY DATABASE | GRANT | sa | NULL | NULL | NULL | NULL | NULL | FALSE | FALSE |
| ENDPOINT | CONNECT | GRANT | sa | TSQL Local Machine | SHARED_MEMORY | NULL | NULL | NULL | FALSE | FALSE |
| ENDPOINT | CONNECT | GRANT | sa | TSQL Named Pipes | NAMED_PIPES | NULL | NULL | NULL | FALSE | FALSE |
| ENDPOINT | CONNECT | GRANT | sa | TSQL Default TCP | TCP | NULL | TSQL | STARTED | FALSE | TRUE |
| ENDPOINT | CONNECT | GRANT | sa | TSQL Default VIA | VIA | NULL | NULL | NULL | FALSE | FALSE |




# Tables

- Identify access to all tables with sensitive data
  - SSN
  - PII
  - Passwords
- Identify hashing or encryption (especially password fields)
  - If encrypted, look at key access/ management
  - Hashing should be "one-way

# Database audit logging




# Audit logging basics

- Track and log events on the database engine
  - Server events
  - Database events
- Uses extended events
- No audit is enabled by default




# Audit trail

- When audit is created, logging destination is defined
- When created, it is *disabled* and must be enabled to log events
- Locations
  - Event log
    - Windows Security event log
    - Windows application event log
  - File on the OS file system
    - Restrict access to the file and its location

# Audit trail leading practices

- If using the event log as an audit destination
  - Avoid using the Windows Application event log
    - Any authenticated user can read and write to this event log (less secure)
- If using an OS file as the audit destination
  - Define an audit on master.sys.fn_get_audit_file
- Always audit actions of "dbo" for all databases




# Topics I did not cover

- Schema security audit
- Replication and backups
- Transparent Data Encryption (TDE)




# Q&A

# References

- Microsoft
  - SQL Server books online - https://msdn.microsoft.com/en-us/library/ms130214(v=sql.105).aspx
  - Securing SQL Server - https://technet.microsoft.com/en-us/library/bb283235(v=sql.110).aspx
  - Checklist - https://technet.microsoft.com/en-us/library/ff848786(v=sql.105).aspx
- Securing SQL Server 2nd edition - Denny Cherry - ISBN 978-1-59749-947-7
- Center for Internet Security benchmarks - http://benchmarks.cisecurity.org/downloads/browse/?category=benchmarks.servers.database.mssql
- DISA STIGs - http://iase.disa.mil/stigs/Pages/index.aspx
  - STIG viewer - http://iase.disa.mil/stigs/Pages/stig-viewing-guidance.aspx
- Database weekly - http://databaseweekly.com
- ISACA - http://www.isaca.org/Journal/archives/2015/Volume-1/Pages/Auditing-SQL-Server-Databases-Using-CAATs.aspx




# Thank you

ron.reidy@gmail.com