Interested in learning more about security?

SANS Institute InfoSec Reading Room

Forensic Analysis of a SQL Server 2005 Database Server

Forensic Analysis of a SQL Server 2005 Database Server

GCFA Gold Certification

Author: Kevvie Fowler, GCFA, CISSP, MCTS, MCSD, MCDBA, MCSE

kevvie.fowler@emergis.com

Adviser: Joey Niem

Accepted: April 1, 2007

Outline

Investigation Introduction

On March 1st, 2007, I received a call from a client who stated that they may have been a victim of a security incident sometime over the past 24 hours. They believed unauthorized modifications were made to their production database server which had resulted in erroneous product shipments and financial loss to the company. Due to the mission critical nature of the system, it could not be taken off-line unless significant evidence of system misuse could be identified.

Step 1: Verification

Upon arriving on scene, I was briefed on the situation and learned that the SQL Server 2005 database server contained a single user database which was the foundation of an online-sales application. The client also informed me that they had received a call from a credit card company regarding a suspicious transaction that was charged to a client card by their company.

Because the server could not be taken off-line, a live analysis was performed. During a live analysis volatile and non volatile data is viewed and acquired with the assistance of the live target operating system[1]. During a forensic investigation you should utilize binaries on the target system as little as possible as they may be corrupt or tampered with thus skewing their output.

The incident response CD-Rom used in this investigation contains traditional incident response tools in addition to SQL utilities and libraries which allow ad-hoc query submission to SQL Servers using minimal assistance from the un-trusted host.

To begin the incident verification, Windows Forensic Tool v1.0.03 will be used with a customized configuration file. This configuration file will execute Distributed Management Views (DMV), Database Consistency Checker (DBCC) commands and other vendor issued procedures to gather data which can be used to prove or disprove the occurrence of an intrusion. For more information on the customized Windows Forensic Tool Chest configuration file, refer to Appendix A of this document.

At precisely 10:02 AM, server time, the client's system logged into the PRODSQL05 SQL Server interactively under the user context Administrator. Upon logging into the system, it was observed that the system tray contained no third party application icons and the operating system appeared to be Windows 2003 Standard Edition. At 10:03 AM, server time, I assumed command of the console to begin the investigation. My Forensic Response CD was inserted into the computer and a trusted command shell was launched by issuing the *"D:\FResponse\cmd.exe"* command. Using the full file path in addition to the binary name ensures that the binary is loaded from the trusted CD. The un-trusted host may contain binaries with matching names to the binaries contained on my response CD. If these binaries are present within a directory referenced in the path variable of the target host, the un-trusted binaries can be loaded in error. To eliminate the possibility of this occurring, the full file location in addition to the binary name will be used during this investigation.

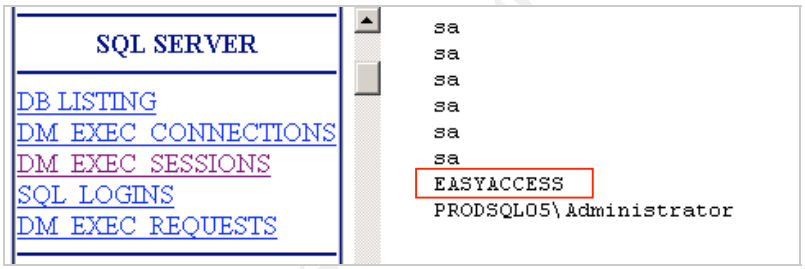
The outputs from the tools run during this investigation, will be saved on the trusted forensic workstation as opposed to the un-trusted target host. From the command shell, the *"D:\FResponse\net use * \\192.168.1.174\$Acquisition"* command was issued to map a drive from the target host to sterile storage media located on my forensic laptop which was connected to the network under IP Address 192.168.1.174.

The "$Acquisition" share is hidden and password protected to help ensure the integrity

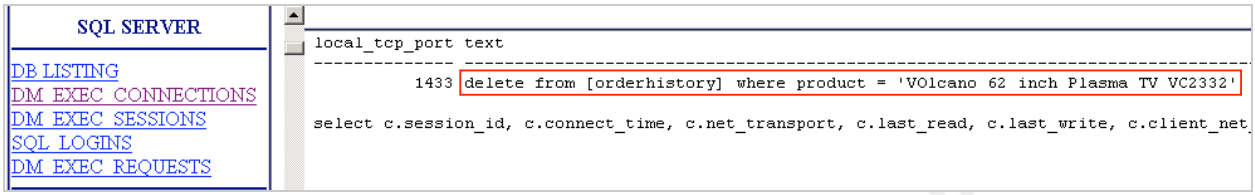
of the data within. It was noted that the drive letter associated with the net use command was connected as "E:\" on the target host. The *"D:\FResponse\wft.exe –dst E:\"* command was issued to launch the customized Windows Forensic Toolchest v1.0.03 instance which gathered volatile database and operating system data from the target system and securely stored it on the forensic workstation.

Once Windows Forensic Toolchest was finished executing, the results were analyzed and the following notable events were identified.

SQL Server reserves Sessions #50 and lower for internal SQL Server processes, discounting these, it was identified that two sessions were currently active on the SQL Server. The first Session ID # 52 which belonged to the instance of WFT executing under the local Administrator context and the second was Session #51 belonging to an unknown user operating under the login EASYACCESS. This session had been established at 7:58 AM that morning. Because the login name was unconventional, it was flagged for client verification.



SQL Server 2005 maintains a record of the last SQL statement executed by a given session. Viewing this history for the connected users led to the identification of a suspicious transaction.



The audit policy active on the target system was configured to log successful logins only, and not login failures. However, SQL Server maintains its own log that records database related service errors in addition to authentication data. The error log was stored within the *"c:\Program Files\Microsoft SQL Server\MSSQL.1\MSSQL\LOG"* directory of the target system. Review of the error log identified several hundred failed login attempts in succession against the sa account, followed by its successful login. This activity is normally attributed to evidence of a successful brute force attack against the database server.

```
2007-03-02 07:39:08.60 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:08.80 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:08.80 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:09.00 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:09.00 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:09.20 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:09.20 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:09.40 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:09.40 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:09.60 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:09.60 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:09.80 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:09.80 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:10.00 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:10.00 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:10.20 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:10.20 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:10.40 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:10.40 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:10.60 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:10.60 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:10.80 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:10.80 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:11.00 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:11.00 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:11.20 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:11.20 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:53:07.39 Logon       Login succeeded for user 'sa'. Connection: non-trusted. [CLIENT: 192.168.1.20]
```

To further investigate the above findings, the configuration of the SQL Server needed to be obtained. SQLCMD, a Microsoft issued utility which allows the submission of ad-hoc SQL

statements and scripts to a MS SQL Server will be used from the trusted incident response CD. The ad-hoc query capabilities of this tool will be used during the remainder of this investigation.

The *"D:\FResponse\Sqlcmd –S PRODSQL05 –e –s","* command was executed from the trusted command prompt which opened a connection to the SQL Server using the interactive user context. The *"-e"* switch forces SQLCMD to echo our input statements into the SQL result files and the "-s","" switch ensures the outputs are comma delimited which will allow the results to be imported into another application for deeper analysis.

After logging in, an output file was established to log the SQL statements and their associated results securely to my forensics workstation.

```
:out e:\initialconnection.txt
```

A MD5 hash will be created on each output file to ensure data integrity. When a connection is made to SQL Server the default database context configured under the user Login Properties will be used. To ensure the database context was indeed set for the OnlineSales database the following command was issued:

```
use OnlineSales
go
```

Results: initialconnection.txt

SQL Server 2005 can be configured to use either Windows Authentication, which allows the host operating system to authenticate users, or Mixed Mode authentication, which allows authentication to occur at either the Operating System or independently within SQL Server[4]. There are also various logging options within SQL Server to log successful and/or failed login attempts. To verify the active configuration settings of the subject server the following command was run:

xp_loginconfig

Results: xp_loginconfig--onlinesales.txt

The following results were produced and show that the server is set for Mixed Mode authentication and is configured to log both successful and failed login attempts.

```
name                          ,config_value
------------------------------,----------------------------
login mode                    ,Mixed
default login                 ,guest
default domain                ,ESALECO
audit level                   ,all
set hostname                  ,false
map _                         ,domain separator
map $                         ,NULL
map #                         ,-
```

Authorization within SQL Server 2005 is controlled by two gates. The first gate ensures that users are authenticated at the database instance and the second ensures that users have the appropriate permissions to access the various databases and database objects. During the verification step of this investigation we identified that the SQL server login EASYACCESS was logged into the server. However because the investigation is on the OnlineSales database the database permissions will need to be checked to ensure that the EASYACCESS account has access to this specific database. The following query was run to gather a list of all database users within the OnlineSales database:

*Select * from sys.database_principals where type = 'S' or type = 'U' order by create_date, modify_date*

Results: db_principals-onlinesales.txt

This query produced the following results which show that the EASYACCESS user account does have access to the OnlineSales database:

name	principal_id	type	type_desc	default_schema_name	create_date	modify_date
sys	4	S	SQL_USER	NULL	38639	38639
Lance	5	U	WINDOWS_USER	dbo	39140	39140
EASYACCESS	6	S	SQL_USER	dbo	39143	39143

The Microsoft extended procedure *"xp_cmdshell"* allows users to execute dos commands within the underlying host operating system using their SQL client. This can allow an attacker who compromises the SQL Server to then launch attacks against the underlying host operating system. However, this procedure is disabled by default in SQL Server 2005. To verify its current state, the following command was executed:

```
Select * from sys.configurations
```

Results: sys.configurations.txt

The results showed that this procedure was disabled therefore the assumption is made that database users are unable to execute operating system level commands on the host.

configuration_id	name	value	minimum	maximum	value_in_use	description	...
16390	xp_cmdshell	0	0	1	0	Enable or disable command shell	...
16391	Ad Hoc Distributed Queries	0	0	1	0	Enable or disable Ad Hoc Distributed Queries	...

At approximately 10:45 AM, the initial findings were presented to the client who verified that the EASYACCESS account was an anomaly and not created for any legitimate business purpose. It was also disclosed that the Online Sales application was down for maintenance therefore no one should have been logged on to the OnlineSalesdatabase or have executed the identified delete statement.

At 11:01 AM the client authorized a full forensic investigation to be performed on the server to determine the scope and impact of the intrusion. At 11:05 AM The SQL Server was

disconnected from the production network and plugged into a 4 port DLINK hub to isolate the server and prevent further modification by the unknown user.

Step 2: System Description

As previously stated in the verification section of this document, upon login to the target server the default Microsoft background was visible on the server console and there were no third party applications visible within the system tray. The following system profile was gathered from information provided by the client as well as investigator findings gathered during the verification step:

System Name	PRODSQL05
Serial Number	US822301223
System Operating System	Microsoft Windows Server 2003 Service Pack 1
Database Version	9.00.1399.06
System Function	Function as a backend database to an online order processing system
Physical Description	The system contained 3 peripheral network cards, one appeared to be a video card, and the remaining two appeared to be network cards, however, only a single network card was actually connected to the network.

Asset Photographs:

Step 3: Evidence Collection

As time elapses after a security incident, evidence can be overwritten by legitimate and/or malicious system activity. Databases can contain large data stores which result in a high data acquisition cost. To help ensure priority is given to the data sources most likely to contain relevant data to support the investigation, it's my expert opinion that relevant data sources be

assigned a significance and also a volatility value between 1 -5 with, 5 being of higher significance and/or volatility. The following values should be used in the following formula to determine priority [10 - (significance rating) + (volatility rating) = priority]. Using the above formula, the data stores relevant in this investigation were prioritized as follows:

Item	Importance	Volatility	Priority
SQL Server Connections & Sessions	5	5	**0**
Transaction Log(s)	5	4	**1**
SQL Server Logs	4	3	**3**
SQL Server Database Files	3	2	**5**
System Event Logs	2	2	**6**

Now that data stores have been identified and prioritized, the actual data acquisition can take place.

SQL Server connection & session data

Related information was successfully captured via the customized Windows Forensic Tool chest tool executed during the verification stage of this investigation.

Transaction Logs

The SQL Server transaction log contains a record of all insert, update and delete statements made within the database. For performance reasons SQL Server does not immediately write these events to the physical data files. Instead changes are written to the log file to buffer and later written to the data files.

A single SQL Server database can utilize multiple database files and multiple transaction logs. The number of files and locations will need to be identified for the OnlineSales database.

Using the trusted SQLCMD session, the following SQL query is executed to gather the database file information:

```
sp_helpdb OnlineSales
```

Results: sp_helpdb-onlinesales.txt

The below results were returned from the above SQL query and show that the OnlineSales database is currently using one physical data file ending with the ".mdf" extension and two transaction log files ending with the ".ldf" extension. These files are contained within separate Windows file locations.

name	fileid	filename	…
OnlineSales	1	C:\Program Files\Microsoft SQL Server\MSSQL.1\MSSQL\DATA\OnlineSales.mdf	…
OnlineSales_log	2	C:\Program Files\Microsoft SQL Server\MSSQL.1\MSSQL\DATA\OnlineSales_log.ldf	…
OnlineSales_log2	3	C:\OtherLogs\OnlineSales_log2.ldf	…

The following SQL query was then executed to dump the contents of the OnlineSales log file to the trusted forensic workstation:

```
dbcc log(OnlineSales)
```

Results: dbcclog-onlinesales.txt

Although a SQL Server database can use multiple physical transaction logs internally, SQL Server splits each physical log file into 4-16 Virtual Log Files (VLFs)[5]. Selected VLFs are marked active at any given time and used to record transactions. SQL Server periodically completes a checkpoint process which flushes changes recorded in the log file to the physical disk file. Once this is complete, SQL Server marks the VLFs containing the fully committed transactions reusable and will overwrite them as required with new log records.

The following SQL Server command was run from within the OnlineSales context to view the logical allocation status of the physical transaction log:

```
dbcc loginfo
```

Results: dbccloginfo-onlinesales.txt

The results of this command may be helpful later in the investigation when it will be determined if the physical transaction log file will be split into virtual log files to separate the active VLFs from the reusable VLFs which may contain historical data relevant in this investigation. In order to obtain a true bit-to-bit copy of the transaction log, the SQL Server service will need to be shutdown in order to release the locks held on the target files. At SQL Server shutdown and startup the database checkpoint process is automatically triggered[5] which, as previously stated before will flush the non committed changes to disk and mark the records as reusable. The following command was executed to force the shutdown of SQL Server.

```
Shutdown
```

Results: shutdown.txt

After the SQL SERVER processes were shutdown, the physical log files were acquired using the dcfldd disk imaging tool which also generated MD5 hashes for the acquired data. These hashes were compared to the hashes of the on disk files to ensure the data was not altered during duplication.

Database files

Using the database file locations retrieved from the results of the "sp_helpdb OnlineSales" command executed earlier in the investigation, the OnlineSales database file was also acquired using the dcfldd tool.

Default SQL Server Trace File

The default configuration of SQL server runs a trace which captures limited activity within the database. This configuration is enabled by default, but can be disabled by a user with sufficient privileges. Using the SQL Server configuration gathered earlier in this investigation, the default trace was confirmed to be enabled.

configuration_id	name	value	minimum	maximum	value_in_use	description
1567	ft crawl bandwidth (max)	100	0	32767	100	Max number of full-text crawl buffers
1568	**default trace enabled**	**1**	**0**	**1**	**1**	**Enable or disable the default trace**
1569	blocked process threshold	0	0	86400	0	Blocked process reporting threshold

During review of the SQL Server installation directory several trace files using the default Microsoft trace naming convention "log_##" were identified. These log files were acquired using the dcfldd tool as they may contain information relevant in this investigation.

SQL Server Error Logs

In addition to the current error log used by SQL Server, historical log data is also maintained. Each time the SQL Server service is restarted, a new error log is created and the existing log is backed up. SQL Server maintains the current error log in addition to 6 log backups. All 7 error logs were acquired using the dcfldd tool. Once all data had been acquired the SQL Server services were restarted.

Step 4: Timeline Creation

Constructing an initial timeline will map out the notable digital events which have been identified thus far and establish an investigation scope which will be used during the Media Analysis phase. Review of the SQL Server error logs obtained during the Evidence Collection step show that the SQL Server instance was restarted on March 01, 2007.

```
2007-03-01 07:26:22.53 Server      SQL Server is now ready for client connections. This is an informational message...
```

This will be the first entry in the timeline. As discovered during the verification step of this investigation on March 2nd, 2007 several hundred failed SQL Server login attempts were recorded within the error log between 7:01 AM to 7:39 AM from IP address 192.168.1.20. Following these failed login attempts were successful logins by the SA account at 7:54 AM and the EASYACCESS account at 8:09 AM from the same IP address.

```
2007-03-02 07:39:11.00 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:11.00 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:39:11.20 Logon       Error: 18456, Severity: 14, State: 8.
2007-03-02 07:39:11.20 Logon       Login failed for user 'sa'. [CLIENT: 192.168.1.20]
2007-03-02 07:53:07.39 Logon       Login succeeded for user 'sa'. Connection: non-trusted. [CLIENT: 192.168.1.20]
2007-03-02 08:09:37.60 Logon       Login succeeded for user 'EASYACCESS'. Connection: non-trusted. [CLIENT: 192.168.1.20]
```

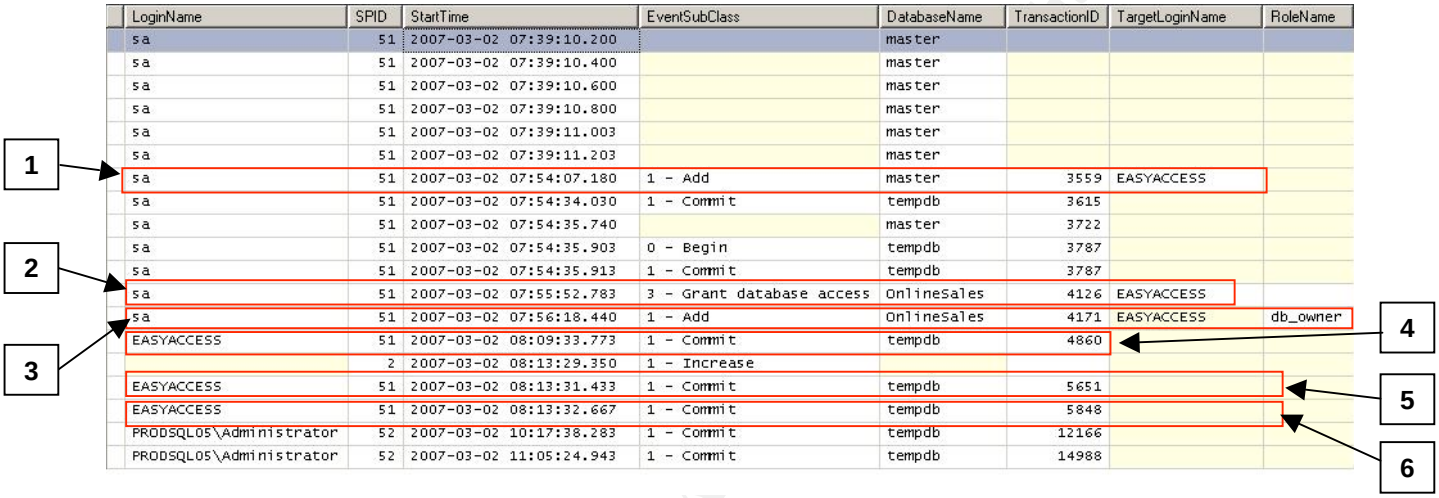
These events will be added to the timeline in addition to the associated Server Process Identifier (SPID). A SPID is a unique number used by SQL Server to track a given session within the database server[2]. The trace files obtained during the evidence collection phase of this investigation were imported into MS SQL Profiler on my forensic workstation for analysis. During review, the following notable events were identified:

(1) Creation of EASYACCESS account

(2) EASYACCESS account is granted access to OnlineSales database

(3) EASYACCESS account is added to ONLINESALES db_owner role

(4-6) Unknown transactions are executed by EASYACCESS account which required tempdb usage. Often DML operations require tempdb usage[2] therefore it is likely that SPID 51 issued DML operations which required object or interim result storage.



LoginName	SPID	StartTime	EventSubClass	DatabaseName	TransactionID	TargetLoginName	RoleName
sa	51	2007-03-02 07:39:10.200		master			
sa	51	2007-03-02 07:39:10.400		master			
sa	51	2007-03-02 07:39:10.600		master			
sa	51	2007-03-02 07:39:10.800		master			
sa	51	2007-03-02 07:39:11.003		master			
sa	51	2007-03-02 07:39:11.203		master			
sa	51	2007-03-02 07:54:07.180	1 - Add	master	3559	EASYACCESS	
sa	51	2007-03-02 07:54:34.030	1 - Commit	tempdb	3615		
sa	51	2007-03-02 07:54:35.740		master	3722		
sa	51	2007-03-02 07:54:35.903	0 - Begin	tempdb	3787		
sa	51	2007-03-02 07:54:35.913	1 - Commit	tempdb	3787		
sa	51	2007-03-02 07:55:52.783	3 - Grant database access	OnlineSales	4126	EASYACCESS	
sa	51	2007-03-02 07:56:18.440	1 - Add	OnlineSales	4171	EASYACCESS	db_owner
EASYACCESS	51	2007-03-02 08:09:33.773	1 - Commit	tempdb	4860		
	2	2007-03-02 08:13:29.350	1 - Increase				
EASYACCESS	51	2007-03-02 08:13:31.433	1 - Commit	tempdb	5651		
EASYACCESS	51	2007-03-02 08:13:32.667	1 - Commit	tempdb	5848		
PRODSQL05\Administrator	52	2007-03-02 10:17:38.283	1 - Commit	tempdb	12166		
PRODSQL05\Administrator	52	2007-03-02 11:05:24.943	1 - Commit	tempdb	14988		

Based on the events identified thus far in the investigation, the following timeline was constructed:

Time	User	SPID	Action
March 1, 2007			
7:26 AM	UNKNOWN	N/A	SQL Server instance is restarted
March 2, 2007			
7:01 AM – 7:39 AM	UNKNOWN	51	SQL Server Brute Force attack launched against PRODSQL05 server
7:54 AM	SA	51	SA SQL Server user account logs into PRODSQL05 server
7:54 AM	SA	51	EASYACCESS account created
7:55 AM	SA	51	EASYACCESS account granted access to OnlineSales database
7:56 AM	SA	51	EASYACCESS account added to OnlineSales db_owner role
8:09 AM	EASYACCESS	51	EASYACCESS SQL Server account logs into

			PRODSQL05 server
8:09 AM	EASYACCESS	51	EASYACCESS account executes unknown transaction within ONLINESALES db
8:13 AM	EASYACCESS	51	EASYACCESS account executes unknown transaction within OnlineSales database
8:13 AM	EASYACCESS	51	EASYACCESS account executes unknown transaction within OnlineSales database
10:17 AM	Administrator	52	Start of Forensic Investigation of database server
11:05 AM	Administrator	N/A	PRODSQL05 server removed from network
11:16 AM	Administrator	52	SQL Server instance shutdown

The application connected to SPID 51 was recorded by SQL Server as "OSQL-32". Performing a *Google*™ search on this name identified the application as a legacy Microsoft command line query tool called OSQL. This will be noted as it may be relevant in the future if an investigation is performed on the unauthorized user's computer.

squelda 1.0	sa	51	2007-03-02 07:39:11.003		0		0
squelda 1.0	sa	51	2007-03-02 07:39:11.203		0		0
OSQL-32	sa	51	2007-03-02 07:54:07.180	1 - Add	1	0X01	0
OSQL-32	sa	51	2007-03-02 07:54:34.030	1 - Commit		0X01	0
OSQL-32	sa	51	2007-03-02 07:54:35.740			0X01	0
OSQL-32	sa	51	2007-03-02 07:54:35.903	0 - Begin		0X01	0
OSQL-32	sa	51	2007-03-02 07:54:35.913	1 - Commit		0X01	0
OSQL-32	sa	51	2007-03-02 07:55:52.783	3 - Grant ...	1	0X01	0
OSQL-32	sa	51	2007-03-02 07:56:18.440	1 - Add	1	0X01	0
OSQL-32	EASYACCESS	51	2007-03-02 08:09:33.773	1 - Commit		0XB89...	0
		2	2007-03-02 08:13:29.350	1 - Increase			0
OSQL-32	EASYACCESS	51	2007-03-02 08:13:31.433	1 - Commit		0XB89...	0
OSQL-32	EASYACCESS	51	2007-03-02 08:13:32.667	1 - Commit		0XB89...	0
SQLCMD	PRODSQL05\Administrator	52	2007-03-02 10:17:38.283	1 - Commit		0X010...	0

Step 5: Media Analysis

The timeline established in the previous step will now be used to set boundaries on the scope of media analysis. Using the timeline, the focus of the investigation will be on activities executed by SPID 51 between 7:54 AM March 1st, 2007 when the unauthorized access was gained to SQL Server and later in the day at 11:05 AM when the system was isolated from the production network.

Before looking at any of the raw SQL Data files, the data types in use within the OnlineSalesdatabase will need to be identified. Unicode is a standard method of mapping SQL Server byte representations (code points) to ASCII characters. The Unicode standard is inclusive of characters which map to all languages throughout the world. SQL Server uses various data types which store Unicode data, however there are some data types used by SQL Server (char(n), varchar(n) & text) which store non-Unicode values[3]. When non-Unicode values are stored within SQL Server, they are converted to a supported data type using the collation setting of the respective table column[3]. If this data is viewed by a computer using a code page which does not cover the range of characters used within the collation setting of the database, data loss can occur which can skew the results[3]. To determine if non-Unicode data was being used by the Order table and the collation setting in place, the following procedure was run:

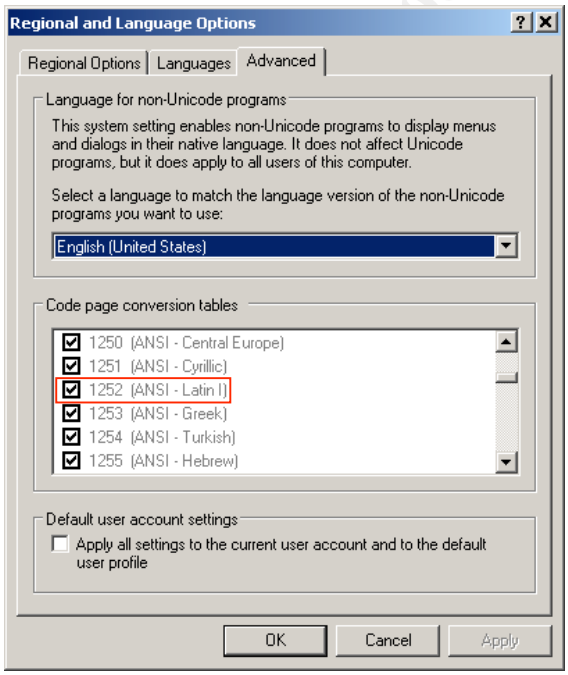
```
sp_tablecollations 'order'
```

Results: sp_tablecollations-onlinesales.txt

The results below show that both Unicode and non-Unicode data is stored within the Order table. The columns storing non-Unicode data are using the SQL_Latin1_General_CP1_CI_AS collation setting.

colid	name	tds_collation	collation
1	OrderID	NULL	NULL
2	FirstName	0x0904D00034	SQL_Latin1_General_CP1_CI_AS
3	LastName	0x0904D00034	SQL_Latin1_General_CP1_CI_AS
4	Address	0x0904D00034	SQL_Latin1_General_CP1_CI_AS
5	City	0x0904D00034	SQL_Latin1_General_CP1_CI_AS
6	State	0x0904D00034	SQL_Latin1_General_CP1_CI_AS
7	ZIP	0x0904D00034	SQL_Latin1_General_CP1_CI_AS
8	CCType	0x0904D00034	SQL_Latin1_General_CP1_CI_AS
9	CCNumber	0x0904D00034	SQL_Latin1_General_CP1_CI_AS
11	ShipStatusID	NULL	NULL
12	OrderDate	NULL	NULL
13	Product	0x0904D00034	SQL_Latin1_General_CP1_CI_AS
14	Price	0x0904D00034	SQL_Latin1_General_CP1_CI_AS

This collation setting was researched on *SQL Server 2005 Books Online* which showed that this collation maps to code page 1252[4]. To verify the code page in use on my forensic workstation, the regional and language options application within control panel on my forensic workstation was viewed. This identified that the forensic workstation was using a compliant code page in order to correctly translate the code points used by SQL Server.



The transaction log acquired during the evidence collection phase was imported into Microsoft Excel using code page 1252. A SQL Server 2005 transaction log contains over 100 columns however only a few columns will contain relevant data based on the scope of this investigation. The following table outlines target columns and their function within this investigation.

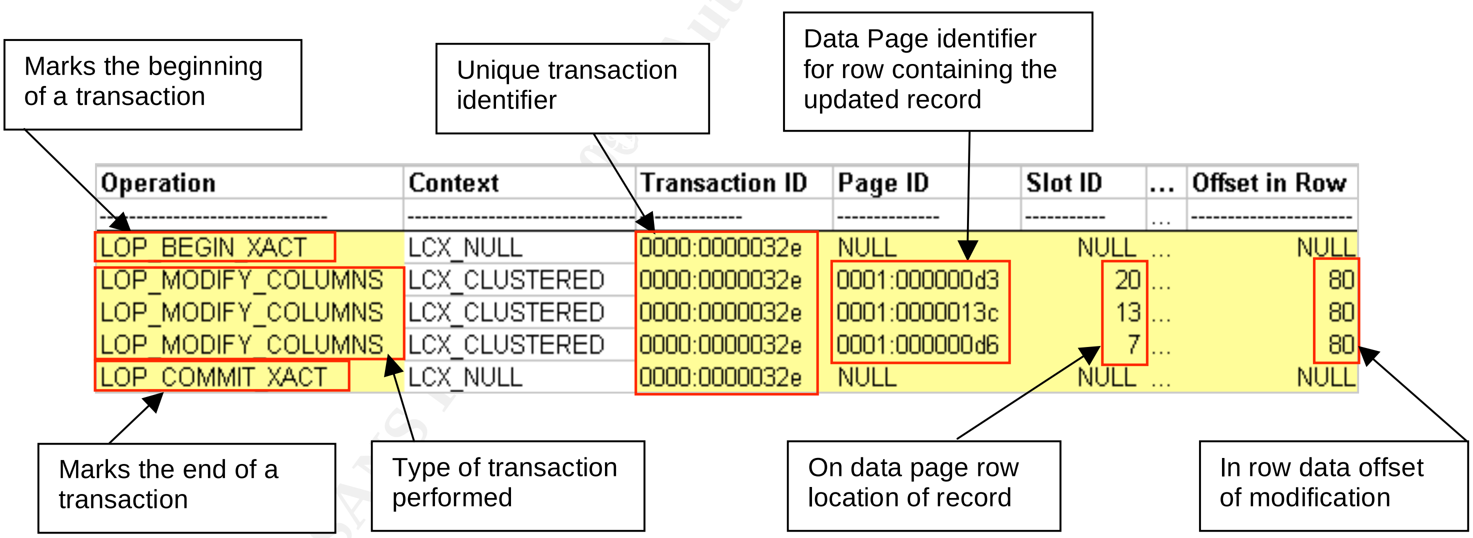
Column	Description
Operation	The type of operation which was performed
PageID	The data page affected by the transaction
SlotID	The row within the data page affected by the transaction
Offset in Row	The first position within the data row affected by the transaction
SPID	The Server Process Identifier
Begin Time	Indicates the transaction start time (server time)
Transaction Name	Classification of the active transaction
End Time	Indicates the transaction end time (server time)
RowLogContents0	The value which was updated by the transaction (Insert, Update statements)
RowLogContents1	The value which was written to disk (Insert, Update statements)

For a listing of all columns within the transaction log, please see Appendix B of this document.

The imported data set was filtered to display only records which were executed by SPID 51 and between the date/time ranges captured in the timeline. The first two transactions identified, were associated with the creation and permission augmentation of the EASYACCESS account which was identified during the trace file review.

Server UID	UID	SPID	Beginlog Status	Begin Time	Transaction Name	Transaction SID	End Time	Transaction Begin
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
0	-1	51	0x01000000	2007/03/02 07:55:52:813	CREATE USER	0x01	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	2007/03/02 07:55:52:833	00000010:00000e1c:0001
0	-1	51	0x01000000	2007/03/02 07:56:18:440	user_transaction	0x01	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL	2007/03/02 07:56:18:450	00000010:00000e1f:0001

The third transaction executed by SPID 51 was an update statement. The transaction log details show that a database transaction ID 0000:0000032e which was an update statement affecting 3 records within 3 separate data pages within the database.



Operation	Context	Transaction ID	Page ID	Slot ID	...	Offset in Row
LOP_BEGIN_XACT	LCX_NULL	0000:0000032e	NULL	NULL	...	NULL
LOP_MODIFY_COLUMNS	LCX_CLUSTERED	0000:0000032e	0001:000000d3	20	...	80
LOP_MODIFY_COLUMNS	LCX_CLUSTERED	0000:0000032e	0001:0000013c	13	...	80
LOP_MODIFY_COLUMNS	LCX_CLUSTERED	0000:0000032e	0001:000000d6	7	...	80
LOP_COMMIT_XACT	LCX_NULL	0000:0000032e	NULL	NULL	...	NULL

A SQL Server data page is an 8192 byte structure which stores database data[5]. A data page can contain multiple rows and each database contains multiple data pages. Data pages are organized into logical groups of 8 called extents[6]. Using the transaction log dump, the first update statement was analyzed, identifying a record on row 20 of Data Page 0001:000000d3. Both the

Page ID and Transaction ID values are stored in hex and when converted to decimal produce the following values:

Identifier	Hex	Decimal
Transaction ID	0000:0000032e	0:814
Data Page	0001:000000d3	1:211

In order to view the raw data pages, the OnlineSales database was attached within SQL Server Management Studio (SSMS) version 9.00.1399.00 on my forensic workstation. Within the newly added OnlineSales database, Microsoft-issued commands and procedures will be used to examine the raw data pages which have been modified.

The following command was issued from within the OnlineSales database context

```
dbcc page (OnlineSales, 1, 211, 1)
```

The above command dumped data page 211 which contained the row which had been modified. The header of the table was examined to identify the base table to which the data page belonged.

```
PAGE HEADER:


Page @0x04304000

m_pageId = (1:211)                    m_headerVersion = 1                   m_type = 1
m_typeFlagBits = 0x0                  m_level = 0                           m_flagBits = 0x0
m_objId (AllocUnitId.idObj) = 87      m_indexId (AllocUnitId.idInd) = 256
Metadata: AllocUnitId = 72057594043629568
Metadata: PartitionId = 72057594039500800                                   Metadata: IndexId = 1
Metadata: ObjectId = 629577281        m_prevPage = (1:314)                  m_nextPage = (1:315)
pminlen = 108                         m_slotCnt = 22                        m_freeCnt = 3263
m_freeData = 5918                     m_reservedCnt = 0                     m_lsn = (16:3686:2)
m_xactReserved = 0                    m_xdesId = (0:0)                      m_ghostRecCnt = 0
m_tornBits = -1731484635

Allocation Status

GAM (1:2) = ALLOCATED                 SGAM (1:3) = NOT ALLOCATED
PFS (1:1) = 0x60 MIXED_EXT ALLOCATED   0_PCT_FULL                           DIFF (1:6) = CHANGED
ML (1:7) = NOT MIN_LOGGED
```

Objectid 629577281 was used as an argument in the following query which was run to resolve the name of the object.

```
Select * from sysobjects where id = 629577281
```

This produced the following output which confirmed that the data page belonged to the Order table.

name	id	xtype	uid	info	status	base_sche	replinfo	parent_obj	crdate	...
Order	629577281	U	1	0	0	0	0	0	2/26/07 4:08 PM	...

The method used by SQL Server to store data depends on the data types in use, the size of each column and the order in which the columns were specified when the table was created. Before the raw data pages were examined, the table schema was first gathered by executing the following command:

```
SELECT sc.colorder, sc.name, st.name as 'datatype', sc.length FROM syscolumns sc,
```

```
systypes st
WHERE sc.xusertype = st.xusertype and sc.id = 629577281
ORDER BY colorder
```

The following output was produced which illustrates the schema of the Order table:

colorder	name	datatype	length
1	OrderID	int	4
2	FirstName	varchar	20
3	LastName	varchar	20
4	Address	varchar	50
5	City	nchar	40
6	State	nchar	4
7	ZIP	nchar	10
8	CCType	varchar	15
9	CCNumber	varchar	20
11	ShipStatusID	int	4
12	OrderDate	datetime	8
13	Product	nvarchar	100
14	Price	nchar	30

Using slotID: 20 and rowoffset 80 which were obtained previously from the transaction log, the specific point within the data row was identified in which the transaction began.

```
Slot 20 Offset 0x147f Length 237

Record Type = PRIMARY_RECORD          Record Attributes =  NULL_BITMAP VARIABLE_COLUMNS

Memory Dump @0x2F3AD47F

00000000:   30006c00 6f000000 53007000 72006900 †0.l.o...S.p.r.i.
00000010:   6e006700 4c006100 6b006500 20002000 †n.g.L.a.k.e. . .
00000020:   20002000 20002000 20002000 20002000 † . . . . . . . .
00000030:   41005a00 31003400 34003100 30000a00 †A.Z.1.4.4.1.0...
00000040:   00000100 00000000 0000e498 00003300 †..............3.
00000050:   2e003500 30002000 20002000 20002000 †..5.0. . . . . .
00000060:   20002000 20002000 20002000 0e0000c0 † . . . . . .....
00000070:   06008400 88009900 9d00ad00 ed00416e †..............An
00000080:   6f736f6e 456d696c 37322053 74617266 †osonEmil72 Starf
00000090:   656c6c20 44726976 65566973 61343931 †ell DriveVisa491
000000A0:   36383833 38343033 38323330 3056006f †6883840382300V.o
000000B0:   006c0063 0061006e 006f0020 00360032 †.l.c.a.n.o. .6.2
000000C0:   00200069 006e0063 00680020 0050006c †. .i.n.c.h. .P.l
000000D0:   00610073 006d0061 00200054 00560020 †.a.s.m.a. .T.V.
000000E0:   00560043 00320033 00330032 00††††††††.V.C.2.3.3.2.
```

Using the table schema obtained earlier, the data type within this row offset is the Price column which contains a 30-byte nchar data type. From the transaction log, the hexadecimal value from the Rowlog0 and Rowlog1 columns were extracted and converted to decimal representation.

RowLog0

Hex	35	00	30	00	30	00	2E	00	30	00	30
ASCII	5		0		0		.		0		0

RowLog1

Hex	2E	00	35	00	30	00	20	00	20	00	20
ASCII	.		5		0		SP		SP		SP

Mapping the data page determined that the offset for the price column is 0x4f (79), as identified, the update statement began at offset 80. This was done so SQL Server did not have to overwrite a value in which it would need to rewrite as part of the transaction. Therefore the offset was augmented by SQL Server from 79 to 80 to compensate. Taking this into consideration, the

statement executed under transaction 0000:0000032e (0:814) was to update the price column from "3500.00" to "3.50":

```
Slot 20 Offset 0x147f Length 237

Record Type = PRIMARY_RECORD         Record Attributes =  NULL_BITMAP VARIABLE_COLUMNS

Memory Dump @0x2F3AD47F

00000000:   30006c00 6f000000 53007000 72006900 †0.l.o...S.p.r.i.
00000010:   6e006700 4c006100 6b006500 20002000 †n.g.L.a.k.e. . .
00000020:   20002000 20002000 20002000 20002000 † . . . . . . . .
00000030:   41005a00 31003400 34003100 30000a00 †A.Z.1.4.4.1.0...
00000040:   00000100 00000000 0000e498 00003300 †..............3.
00000050:   2e003500 30002000 20002000 20002000 †..5.0. . . . . .
00000060:   20002000 20002000 20002000 0e0000c0 † . . . . . .....
00000070:   06008400 88009900 9d00ad00 ed00416e †..............An
00000080:   6f736f6e 456d696c 37322053 74617266 †osonEmil72 Starf
00000090:   656c6c20 44726976 65566973 61343931 †ell DriveVisa491
000000A0:   36383833 38343033 38323330 3056006f †6883840382300V.o
000000B0:   006c0063 0061006e 006f0020 00360032 †.l.c.a.n.o. .6.2
000000C0:   00200069 006e0063 00680020 0050006c †. .i.n.c.h. .P.l
000000D0:   00610073 006d0061 00200054 00560020 †.a.s.m.a. .T.V.
000000E0:   00560043 00320033 00330032 00†††††††.V.C.2.3.3.2.
```

Start of trn.

Start of col.

Using the same steps outlined above, the remaining 2 records updated during this transaction were identified.

```
Slot 13, Offset 0x1450, Length 239, DumpStyle BYTE

Record Type = PRIMARY_RECORD          Record Attributes =  NULL_BITMAP VARIABLE_COLUMNS

Memory Dump @0x2F7AD450

00000000:   30006c00 08010000 53007000 72006900 †0.l.....S.p.r.i.
00000010:   6e006700 4c006100 6b006500 20002000 †n.g.L.a.k.e. . .
00000020:   20002000 20002000 20002000 20002000 † . . . . . . . .
00000030:   41005a00 31003700 30003000 33000100 †A.Z.1.7.0.0.3...
00000040:   00000100 00000000 0000e498 00003300 †..............3.
00000050:   2e003500 30002000 20002000 20002000 †..5.0. . . . . .
00000060:   20002000 20002000 20002000 0e0000c0 † . . . . . .....
00000070:   06008400 8a009b00 9f00af00 ef00436f †..............Co
00000080:   72796e6e 466f776c 65723732 20537461 †rynnFowler72 Sta
00000090:   7266656c 6c204472 69766556 69736135 †rfell DriveVisa5
000000A0:   35313835 33303030 30303030 30303056 †5185300000000000V
000000B0:   006f006c 00630061 006e006f 00200036 †.o.l.c.a.n.o. .6
000000C0:   00320020 0069006e 00630068 00200050 †.2. .i.n.c.h. .P
000000D0:   006c0061 0073006d 00610020 00540056 †.l.a.s.m.a. .T.V
000000E0:   00200056 00430032 00330033 003200††††. .V.C.2.3.3.2.
```

RowLog0

Hex	35	00	30	00	30	00	2E	00	30	00	30
ASCII	5		0		0		.		0		0

RowLog1

Hex	2E	00	35	00	30	00	20	00	20	00	20
ASCII	.		5		0		SP		SP		SP

```
Slot 7, Offset 0x11c6, Length 240, DumpStyle BYTE

Record Type = PRIMARY_RECORD          Record Attributes =  NULL_BITMAP VARIABLE_COLUMNS

Memory Dump @0x2F2AD1C6

00000000:   30006c00 46010000 53007000 72006900 †0.l.F...S.p.r.i.
00000010:   6e006700 4c006100 6b006500 20002000 †n.g.L.a.k.e. . .
00000020:   20002000 20002000 20002000 20002000 † . . . . . . . .
00000030:   41005a00 31003400 34003100 30000a00 †A.Z.1.4.4.1.0...
00000040:   00000100 00000000 0000e498 00003300 †..............3.
00000050:   2e003500 30002000 20002000 20002000 †..5.0. . . . . .
00000060:   20002000 20002000 20002000 0e0000c0 † . . . . . ....
00000070:   06008200 8b009c00 a000b000 f0004162 †..............Ab
00000080:   6965a04f 274e6569 6c6c2037 32205374 †ie.O'Neill 72 St
00000090:   61726665 6c6c2044 72697665 56697361 †arfell DriveVisa
000000A0:   34393136 38383030 30303030 30303030 †4916880000000000
000000B0:   56006f00 6c006300 61006e00 6f002000 †V.o.l.c.a.n.o. .
000000C0:   36003200 20006900 6e006300 68002000 †6.2. .i.n.c.h. .
000000D0:   50006c00 61007300 6d006100 20005400 †P.l.a.s.m.a. .T.
000000E0:   56002000 56004300 32003300 33003200 †V. .V.C.2.3.3.2.
```

RowLog0

Hex	35	00	30	00	30	00	2E	00	30	00	30
ASCII	5		0		0		.		0		0

RowLog1

Hex	2E	00	35	00	30	00	20	00	20	00	20
ASCII	.		5		0		SP		SP		SP

It is noted that all 3 records updated during this transaction were associated with the "Volcano 62 inch Plasma TV VC2332" product.

The fourth transaction executed by SPID 51 was another update statement. The transaction log details show that transaction ID: 0000:0000032f was an update statement affecting 2 records located on 2 separate data pages.

Operation	Context	Transaction ID	Page ID	Slot ID	...	Offset in Row
LOP_BEGIN_XACT	LCX_NULL	0000:0000032f	NULL	NULL		NULL
LOP_MODIFY_ROW	LCX_CLUSTERED	0000:0000032f	0001:000000d3	20		66
LOP_MODIFY_ROW	LCX_CLUSTERED	0000:0000032f	0001:000000d6	7		66
LOP_COMMIT_XACT	LCX_NULL	0000:0000032f	NULL	NULL		NULL

The same process used previously was followed to identify the affected records. The row offset and page ID values obtained from the transaction log were used to identify the specific value updated within the following records:

```
Slot 7 Offset 0x12b6 Length 243

Record Type = PRIMARY_RECORD         Record Attributes =  NULL_BITMAP VARIABLE_COLUMNS

Memory Dump @0x0E64D2B6

00000000:   30006c00 46010000 42006500 6c006c00 †0.l.F...B.e.l.l.
00000010:   65007600 75006500 20002000 20002000 †e.v.u.e. . . . .
00000020:   20002000 20002000 20002000 20002000 † . . . . . .
00000030:   43005400 32003100 30003600 37000a00 †C.T.2.1.0.6.7...
00000040:   00000200 00000000 0000e398 00003300 †.............3.
00000050:   35003000 30002e00 30003000 20002000 †5.0.0...0.0. . .
00000060:   20002000 20002000 20002000 0e0000c0 † . . . . . .....
00000070:   06008200 8b009f00 a300b300 f3004162 †.............Ab
00000080:   6965a04f 274e6569 6c6c2032 32372057 †ie.O'Neill 227 W
00000090:   494e4448 4156454e 20535452 45455456 †INDHAVEN STREETV
000000A0:   69736134 39313638 38303030 30303030 †isa4916880000000
000000B0:   30303056 006f006c 00630061 006e006f †000V.o.l.c.a.n.o
000000C0:   00200036 00320020 0069006e 00630068 †. .6.2. .i.n.c.h
000000D0:   00200050 006c0061 0073006d 00610020 †. .P.l.a.s.m.a.
000000E0:   00540056 00200056 00430032 00330033 †.T.V. .V.C.2.3.3
000000F0:   003200†††††††††††††††††††††††††††††††.2.
```

The data type within this offset of the row is the ShipStatusID which is a 4-byte integer value.

RowLog0

Hex	00	01	00	00
ASCII	00	01	00	00

RowLog1

Hex	00	02	00	00
ASCII	00	02	00	00

```
Slot 20 Offset 0x156c Length 238

Record Type = PRIMARY_RECORD         Record Attributes =  NULL_BITMAP VARIABLE_COLUMNS

Memory Dump @0x0E6CD56C

00000000:   30006c00 6f000000 57006800 69007400 †0.l.o...W.h.i.t.
00000010:   62007900 20002000 20002000 20002000 †b.y. . . . . .
00000020:   20002000 20002000 20002000 20002000 † . . . . . .
00000030:   46004c00 33003200 37003000 31000a00 †F.L.3.2.7.0.1...
00000040:   00000200 00000000 00008e98 00003300 †..............3.
00000050:   35003000 30002e00 30003000 20002000 †5.0.0...0.0. . .
00000060:   20002000 20002000 20002000 0e0000c0 † . . . . . .....
00000070:   06008400 88009a00 9e00ae00 ee00416e †..............An
00000080:   6f736f6e 456d696c 37342048 65726963 †osonEmil74 Heric
00000090:   6b736f6e 20445249 56455669 73613439 †kson DRIVEVisa49
000000A0:   31363838 33383430 33383233 30305600 †1688384038230OV.
000000B0:   6f006c00 63006100 6e006f00 20003600 †o.l.c.a.n.o. .6.
000000C0:   32002000 69006e00 63006800 20005000 †2. .i.n.c.h. .P.
000000D0:   6c006100 73006d00 61002000 54005600 †l.a.s.m.a. .T.V.
000000E0:   20005600 43003200 33003300 3200†††††† .V.C.2.3.3.2.
```

RowLog0

Hex	00	01	00	00
ASCII	00	01	00	00

RowLog1

Hex	00	02	00	00
ASCII	00	02	00	00

It is noted that after querying the ShipStatus table the ShipStatusID value of 1 indicates that an order has been shipped and a value of 2 indicates that the order has yet to be shipped. It is the investigator's belief that the value was updated from 2 to 1 in an attempt to have the customer

repeat shipment of the referenced product to the designated address.

The fifth transaction executed by SPID 51 was an insert statement. The transaction log details show that a database transaction 0000:00000330 affected a single row.

Operation	Context	Transaction ID	Page ID	Slot ID	...	Offset in Row
LOP_BEGIN_XACT	LCX_NULL	0000:00000330	NULL	NULL		NULL
LOP_INSERT_ROWS	LCX_CLUSTERED	0000:00000330	0001:00000138	8		NULL
LOP_COMMIT_XACT	LCX_NULL	0000:00000330	NULL	NULL		NULL

The same procedure used to map the previous update statements to a data pages was followed to identify the inserted record:

```
Slot 8 Offset 0xcf6 Length 188

Record Type = PRIMARY_RECORD         Record Attributes =  NULL_BITMAP VARIABLE_COLUMNS

Memory Dump @0x0E64CCF6

00000000:   30006c00 a1010000 53007000 72006900 †0.l.....S.p.r.i.
00000010:   6e006700 4c006100 6b006500 20002000 †n.g.L.a.k.e. . .
00000020:   20002000 20002000 20002000 20002000 † . . . . . .
00000030:   41005a00 31003400 34003100 3000827c †A.Z.1.4.4.1.0..|
00000040:   23fb0200 00000000 0000e498 00003400 †#.............4.
00000050:   2e003000 30002000 20002000 20002000 †..0.0. . . . . .
00000060:   20002000 20002000 20002000 0e0000c2 † . . . . . .....
00000070:   06008200 87009800 9c00ac00 bc004e69 †..............Ni
00000080:   6e6f426c 61636b37 32205374 61726665 †noBlack72 Starfe
00000090:   6c6c2044 72697665 56697361 35353138 †ll DriveVisa5518
000000A0:   35333030 30303030 30303030 58004200 †530000000000X.B.
000000B0:   4f005800 20003300 36003000 ††††††††††0.X. .3.6.0.
```

Querying the remainder of the transactions showed that no future modifications were made to this slot within the data page 0000:00000330 therefore the data currently residing on the data page remains unchanged from its state as inserted during this transaction. The values contained within this record are as follows:

OrderID = 417

FirstName = Nino

LastName = Black

Address = 72 Starfell Drive

City = SpringLake

State = AZ

ZIP = 14410

CCType = Visa

CCNumber = 5518530000000000

ShipStatusID = 2

OrderDate = March 1, 2007 12:00AM

Product = XBOX 360

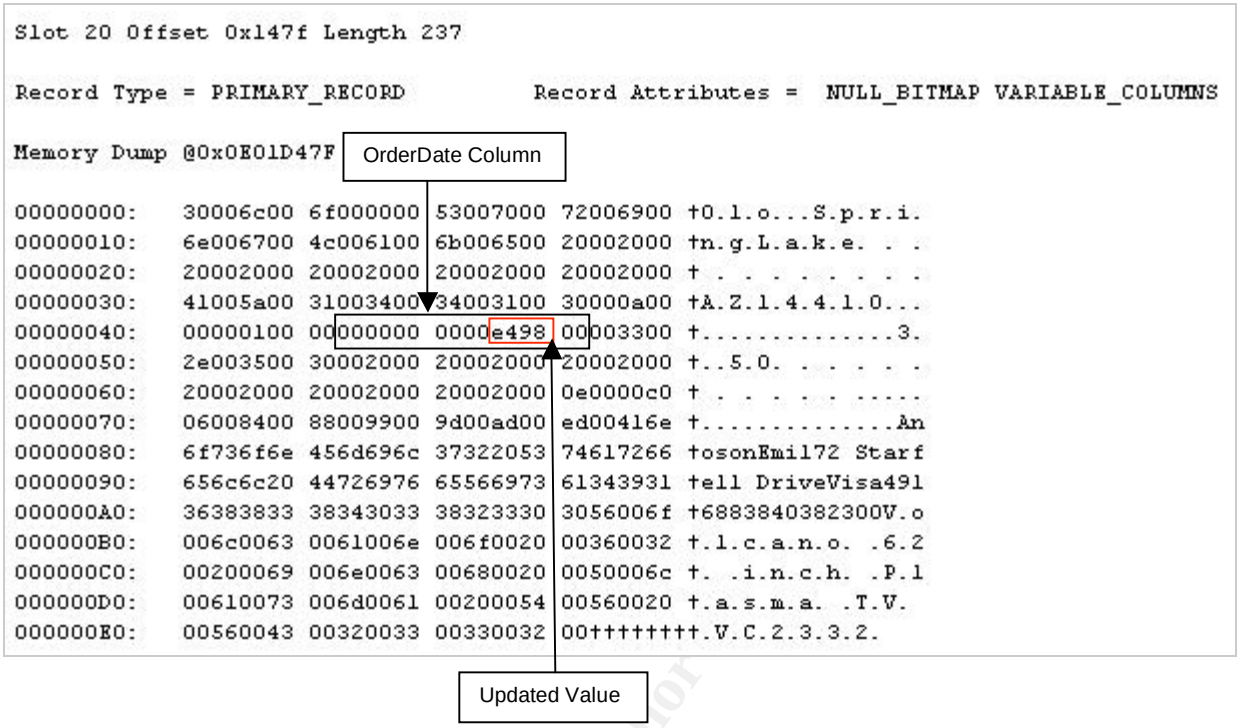
Price = 4.00

The price associated with this item seems inaccurate, and will be flagged for review by the client. It was also noted that the credit card number used in this insert statement was also associated with one of the records updated during transaction 815.

The sixth transaction executed by SPID 51was transaction 0000:00000331 an update statement affecting 3 records.

Operation	Context	Transaction ID	Page ID	Slot ID	...	Offset in Row
LOP_BEGIN_XACT	LCX_NULL	0000:00000331	NULL	NULL		NULL
LOP_MODIFY_ROW	LCX_CLUSTERED	0000:00000331	0001:000000d3	20		74
LOP_MODIFY_ROW	LCX_CLUSTERED	0000:00000331	0001:0000013c	13		74
LOP_MODIFY_ROW	LCX_CLUSTERED	0000:00000331	0001:000000d6	7		74
LOP_COMMIT_XACT	LCX_NULL	0000:00000331	NULL	NULL		NULL

The same procedure used earlier to map the previous update statements to a data pages was followed here and resolved to the Order table. Using the table schema obtained earlier, the data type within this row offset is the OrderDate column which contains an 8-byte datetime data type. The first record updated during this transaction was located on data page 211, slot 20 and the updated column began at offset 74.



The method in which computers store multiple-byte values vary, some use little-endian ordering (LEO) and others use big-endian ordering (BEO)[7]. With little-endian ordering, the most significant byte of the number is placed in the first storage byte; big-endian does the reverse and stores the least significant byte in the first storage byte. Microsoft operating systems use little-endian ordering[7], which is also true in the way SQL Server stores numeric values.

From the transaction log the hexadecimal values from the Rowlog0 and Rowlog1 columns were extracted, switched into LEO and converted to decimal representation.

RowLog0

Hex (BEO)	0x0000000000BD9800
Hex (LEO)	0x000000000098BD00
Decimal	39101

RowLog1

Hex (BEO)	0x0000000000E49800
Hex (LEO)	0x000000000098E400
Decimal	39140

The datetime data type within SQL Server breaks an 8-byte date value into 2 fragments, the first being the number of days before or after January 1st, 1900 and the second being the number of clock computer ticks after midnight with a tick occurring every 3.33 milliseconds[5]. Applications using the datetime data type to store date values only, will have a default time value of 00:00:00:000 which represents midnight[5]. The decimal representation of the RowLog1 column is 39140 which when added in days to January 1st, 1900 gives us the date of March 01, 2007. The order date of this record was updated from January 21, 2007 to March 01, 2007.

This procedure was used to identify the remaining two values which were updated within transaction 0000:00000331.

```
Slot 13 Offset 0x1450 Length 239

Record Type = PRIMARY_RECORD          Record Attributes =  NULL_BITMAP VARIABLE_COLUMNS

Memory Dump @0x0E8DD450
```

OrderDate Column

```
00000000:   30006c00 08010000 53007000 72006900 †0.l.....S.p.r.i.
00000010:   6e006700 4c006100 6b006500 20002000 †n.g.L.a.k.e. . .
00000020:   20002000 20002000 20002000 20002000 † . . . . . . . .
00000030:   41005a00 31003700 30003000 33000100 †A.Z.1.7.0.0.3...
00000040:   00000100 00000000 0000e498 00003300 †..............3.
00000050:   2e003500 30002000 20002000 20002000 †..5.0. . . . . .
00000060:   20002000 20002000 20002000 0e0000c0 † . . . . . .....
00000070:   06008400 8a009b00 9f00af00 ef00436f †..............Co
00000080:   72796e6e 466f776c 65723732 20537461 †rynnFowler72 Sta
00000090:   7266656c 6c204472 69766556 69736135 †rfell DriveVisa5
000000A0:   35313835 33303030 30303030 30303056 †5185300000000000V
000000B0:   006f006c 00630061 006e006f 00200036 †.o.l.c.a.n.o. .6
000000C0:   00320020 0069006e 00630068 00200050 †.2. .i.n.c.h. .P
000000D0:   006c0061 0073006d 00610020 00540056 †.l.a.s.m.a. .T.V
000000E0:   00200056 00430032 00330033 003200††††. .V.C.2.3.3.2.
```

Updated Value

RowLog0 (on disk value prior to transaction)

Hex (BEO)	0x0000000000BD9800
Hex (LEO)	0x000000000098BD00
Decimal	39101

RowLog1 (committed transaction value)

Hex (BEO)	0x0000000000E49800
Hex (LEO)	0x000000000098E400
Decimal	39140

```
Slot 7 Offset 0x11c6 Length 240

Record Type = PRIMARY_RECORD          Record Attributes =  NULL_BITMAP VARIABLE_COLUMNS

Memory Dump @0x0E74D1C6
```

OrderDate Column

```
00000000:   30006c00 46010000 53007000 72006900 †0.l.F...S.p.r.i.
00000010:   6e006700 4c006100 6b006500 20002000 †n.g.L.a.k.e. . .
00000020:   20002000 20002000 20002000 20002000 † . . . . . . . .
00000030:   41005a00 31003400 34003100 30000a00 †A.Z.1.4.4.1.0...
00000040:   00000100 00000000 0000e498 00003300 †..............3.
00000050:   2e003500 30002000 20002000 20002000 †..5.0. . . . . .
00000060:   20002000 20002000 20002000 0e0000c0 † . . . . . .....
00000070:   06008200 8b009c00 a000b000 f0004162 †..............Ab
00000080:   6965a04f 274e6569 6c6c2037 32205374 †ie.O'Neill 72 St
00000090:   61726665 6c6c2044 72697665 56697361 †arfell DriveVisa
000000A0:   34393136 38383030 30303030 30303030 †4916880000000000
000000B0:   56006f00 6c006300 61006e00 6f002000 †V.o.l.c.a.n.o. .
000000C0:   36003200 20006900 6e006300 68002000 †6.2. .i.n.c.h. .
000000D0:   50006c00 61007300 6d006100 20005400 †P.l.a.s.m.a. .T.
000000E0:   56002000 56004300 32003300 33003200 †V. .V.C.2.3.3.2.
```

Updated Value

RowLog0 (on disk value prior to transaction)

Hex (BEO)	0x0000000000CE9800
Hex (LEO)	0x000000000098CE00
Decimal	39118

RowLog1 (committed transaction value)

Hex (BEO)	0x0000000000E49800
Hex (LEO)	0x000000000098E400
Decimal	39140

The seventh transaction executed by SPID 51 was transaction 0000:00000332, a delete statement

affecting a single record.

Operation	Context	Transaction ID	Page ID	Slot ID	...	Offset in Row
LOP_BEGIN_XACT	LCX_NULL	0000:00000332	NULL	NULL		
LOP_DELETE_ROWS	LCX_MARK_AS_GHOST	0000:00000332	0001:00000158	24		
LOP_SET_BITS	LCX_PFS	0000:00000000	0001:00000001	0		
LOP_COMMIT_XACT	LCX_NULL	0000:00000332	NULL	NULL		

This record will be further examined during the data recovery stage of this investigation.

Step 6: Data Recovery

The seventh transaction executed by SPID 51was transaction 0000:00000332, a delete statement affecting a single record. When a record is deleted within SQL Server, it is marked as a ghost[5], which tells the database engine to hide it from future query results even though the underlying data still resides within the data page. A garbage clean-up process runs periodically within SQL Server to physically remove the ghost records within the data pages so the space can be reused. Ghost records contained within a data page are flagged within the page header. Examining the header of the page 0001:0000000158 (1:344) containing the deleted row showed that the m_ghostRecCnt value was set at 0 indicating that the ghost records had already been physically removed from the data page.

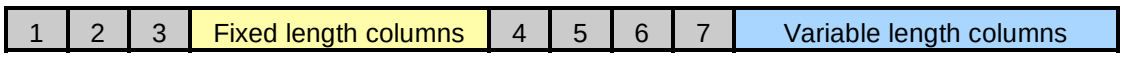
```
Page @0x043D0000

m_pageId = (1:344)                  m_headerVersion = 1                 m_type = 1
m_typeFlagBits = 0x4                m_level = 0                         m_flagBits = 0x8200
m_objId (AllocUnitId.idObj) = 78    m_indexId (AllocUnitId.idInd) = 256
Metadata: AllocUnitId = 72057594043039744
Metadata: PartitionId = 72057594039042048                               Metadata: IndexId = 1
Metadata: ObjectId = 245575913      m_prevPage = (1:190)                m_nextPage = (1:191)
pminlen = 108                       m_slotCnt = 27                      m_freeCnt = 2876
m_freeData = 6899                   m_reservedCnt = 0                   m_lsn = (16:3626:1)
m_xactReserved = 0                  m_xdesId = (0:818)                  m_ghostRecCnt = 0
m_tornBits = -1097693874
```

Using the same procedure used earlier in this document to map a data page to the owning table identified that the data page associated in this transaction mapped to the OrderHistory table. This table had an identical schema to that of the Order table. Within the transaction log, the following value was obtained from the RowLog0 column of the delete statement:

"0x30006C009F0000005000610079006500740074006500200020002000200020002000
2000200020002000200020002000200046004C00310036003600300032000100000000000003A980
0003300350030003000 2E00300030002000200020002000200020002000200020000E0000C0060082
00860098009C00AD00CD00427572744361766532323720537461726765 6C6C2044726976655
669736136353930333430303334333232333230305 66F6C63616E6F20363220696E636820506
C61736D6120545620564332333332"

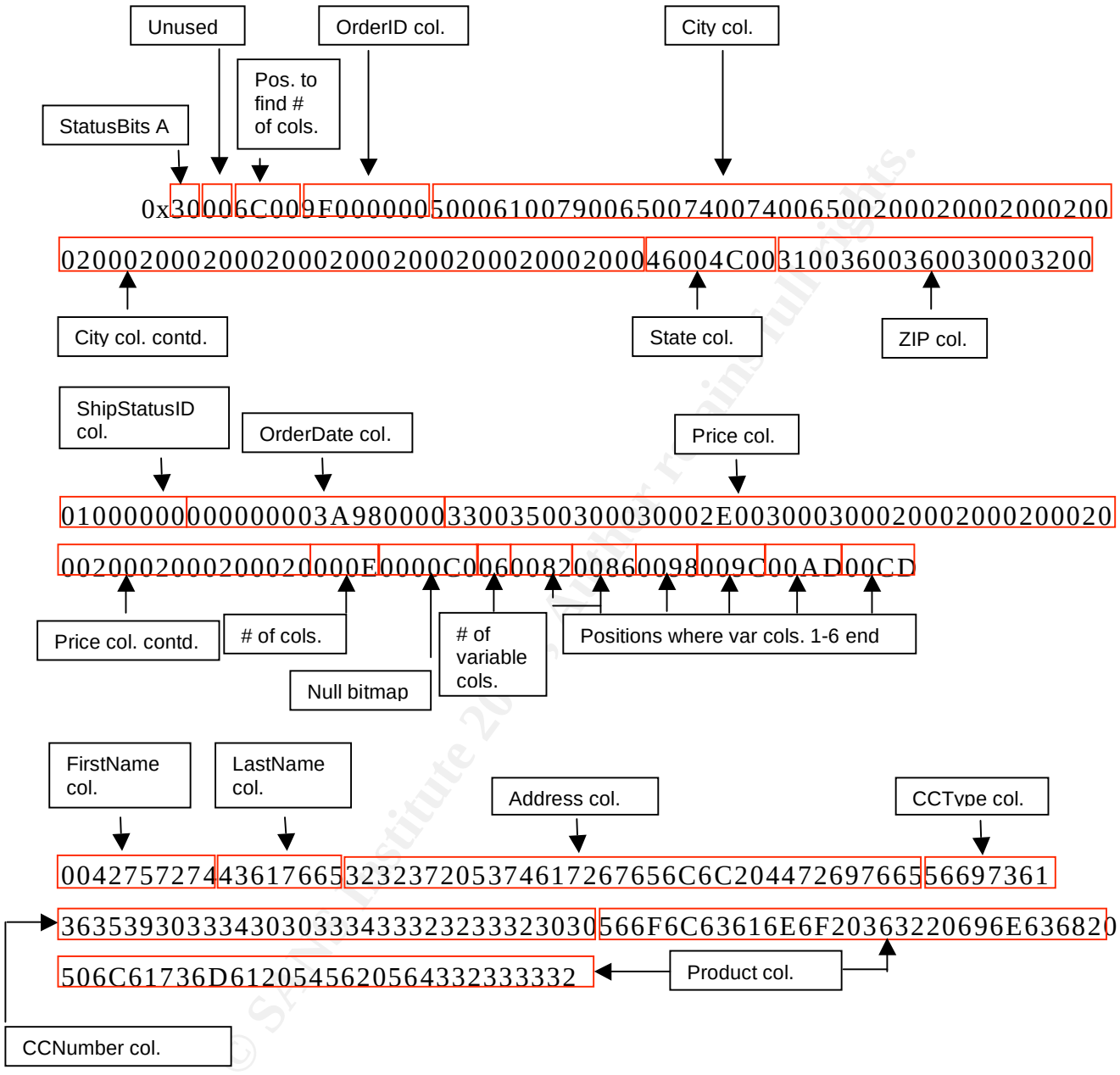
The data above is the actual data row deleted from the data page during the transaction. To determine exactly what customer data had been deleted, it was necessary to reconstruct the data row. SQL Server uses two different data row structures, one for rows which contain fixed length columns only, and another for rows containing variable length columns and/or fixed length columns. Based on the schema obtained earlier in this investigation we know that the Order table contains both fixed and variable length data types. The data row structure for a variable length row is as follows:



Source: Inside SQL Server 2005 The Storage Engine[5]

Legend		
Item	**Storage Allocation**	**Description**
1	1 byte	StatusBits A contains data row properties[5]
2	1 byte	Unused in SQL Server 2005[5]
3	2 bytes	Row offset to in row location containing the number of columns in the data row[5]
Fixed length columns	Fixed column length for all fixed columns	Location of in row fixed length data columns[5]
4	2 bytes	Total number of columns in data row[5]
5	1 bit for each row column	Null Bitmap[5]
6	2 bytes	Number of variable length columns within data row[5]
7	2 bytes for each variable length column	Row offset marking the end of each variable length column[5]
Variable length columns	Used length of all variable length columns	Location of in row variable length data columns[5]

Using the above row structure, and the data obtained from the RowLog0 column of the transaction log, the data row was reconstructed.



Switching the appropriate hex values into LEO, and converting the values to decimal/ASCII representation produced the following.

OrderID: 159

FirstName: Burt

LastName: Cave

Address: 227 Stargell Drive

City: Payette

State: FL

ZIP: 16602

CCType: Visa

CCNumber: 65903400343223200

ShipStatusID: 1

OrderDate: September 11th, 2006

Product: Volcano 62 inch Plasma TV VC2332

Price: 3500.00

Now that all of the executed transactions have been identified, the timeline was updated to reflect the notable discoveries.

Time	User	SPID	Action
March 1, 2007			
7:26 AM	UNKNOWN	N/A	SQL Server instance is restarted
March 2, 2007			
7:01 AM – 7:39 AM	UNKNOWN	51	SQL Server Brute Force attack launched against PRODSQL05 server from IP 192.168.1.20
7:54 AM	SA	51	SA SQL Server user account logs into PRODSQL05 server from IP address 192.168.1.20 using OSQL.exe
7:54 AM	SA	51	EASYACCESS account is created
7:55 AM	SA	51	EASYACCESS account is granted access to OnlineSales database
7:56 AM	SA	51	EASYACCESS account added to OnlineSales db_owner role
8:09 AM	EASYACCESS	51	SQL Server account logs into PRODSQL05 server

			from IP address 192.168.1.20
8:17 AM	EASYACCESS	51	Transaction 814 is executed which updates the price of 3 Volcano Plasma TV orders from $3500.00 to $3.50
8:20 AM	EASYACCESS	51	Transaction 815 is executed which updates the shippingstatusID column on Volcano Plasma TV orders from 1 (product shipped) to 2 (product not shipped)
8:31 AM	EASYACCESS	51	Transaction 816 is executed which inserts an order for an XBOX 360 billed to the credit card of another database customer.
8:37 AM	EASYACCESS	51	Transaction 817 is executed which sets the orderdate on Plasma TV orders to February 28, 2007
8:38 AM	EASYACCESS	51	Transaction 818 is executed which deletes a previous order from the OrderHistory table for a Volcano Plasma TV at a price of $3500.00
10:17 AM	Administrator	52	Start of Forensic Investigation of database server
11:05 AM	Administrator	N/A	PRODSQL05 server removed from network
11:16 AM	Administrator	52	SQL Server instance shutdown

Step 7: String Search

As stated previously in this report, a single physical transaction log file is logically partitioned and split into 4-16 Virtual Log Files (VLFs) by SQL Server. Only a subset of these VLFs will be active at any one point. It is possible that the inactive VLFs at one point in time were active and may contain past transaction data which is relevant within this investigation. Review of the active transaction log file used throughout this investigation identified that the earliest log entry was 7:26 AM March 1st, 2007 and the latest was 11:16 AM March 2nd, 2007. This date range is inclusive of the scope of the investigation therefore further review of VLFs is not required.

The published Microsoft tools which interpret transaction logs support only active VLFs. Further investigation into transactions which occurred outside of the scope of this investigation will require sting searches to be performed on the inactive areas of the transaction log to identify rows for reconstruction.

Investigation Summary

In conclusion, after gathering and analyzing all evidence, it is in the investigator′s expert opinion that on the Morning of March 1st, 2007, an unauthorized user connecting from IP 192.168.1.20 executed a successful brute force attack against the PRODSQL05 server. Once access was gained to the database, a connection was made using the Microsoft OSQL client to create a backdoor account named EASYACCESS. This account was used by the user to fraudulently insert an erroneous product order for an XBOX 360 with the incorrect price of $4.00. This order was billed to Visa card number 5518530000000000 which belongs to another customer within the database. It is noted that the mailing addresses used within the fraudulent order differs from the address of the compromised user and may belong to the unauthorized user.

In addition to inserting a fraudulent order, the unauthorized user performed the following updates to existing Volcano 62 inch Plasma TV VC2332 orders within the Order table.

- Order dates were set to February 28th, 2007
- Prices were updated from $3500.00 to $3.50
- The shippingstatusID column was updated from 2 to 1

A single record was also deleted from the Order table for a past Volcano 62 inch Plasma TV VC2332 by the user.

The unauthorized user is believed to have had a general understanding of Transact-SQL (TSQL) syntax in order to have been capable of executing the database transactions via the OSQL command line interface and moderate knowledge of the OnlineSales database schema.

Appendix A

The following was text was added to WFT configuration file

```
################
# SQL SERVER   #
################
M       NA      NA      NA      NA      SQL SERVER NA
V       SQLCMD.RLL      341369b133a26556d963427384ca89ba        NA      NA      NA
        Required by sqlcmd.exe
EVH     SQLCMD.exe 28731c04b854cc1570dbdacc89a6c3f2      %s -E  -Q "sp_helpdb" >
%s%s%s      sp_helpdb       DB LISTING  SP_HELPDB  SQL SERVER
EH      SQLCMD.exe 28731c04b854cc1570dbdacc89a6c3f2      %s -E  -Q "select c.session_id,
c.connect_time, c.net_transport, c.last_read, c.last_write, c.client_net_address, c.local_tcp_port,
s.text from sys.dm_exec_connections c cross apply sys.dm_exec_sql_text
(c.most_recent_sql_handle) s" > %s%s%s    dm_exec_connections
        DM_EXEC_CONNECTIONS     DM_EXEC_CONNECTIONS     SQL SERVER
EH      SQLCMD.exe 28731c04b854cc1570dbdacc89a6c3f2      %s -E  -Q "select * from
sys.dm_exec_sessions" > %s%s%s   dm_exec_sessions      DM_EXEC_SESSIONS
        DM_EXEC_SESSIONS        SQL SERVER
EH      SQLCMD.exe 28731c04b854cc1570dbdacc89a6c3f2      %s -E  -Q "select name,
type_desc, create_date, modify_date from sys.sql_logins order by create_date, modify_date" >
%s%s%s      sql_logins              SQL_LOGINS              SQL_LOGINS
        SQL SERVER
EH      SQLCMD.exe 28731c04b854cc1570dbdacc89a6c3f2      %s -E  -Q "select * from
```

sys.dm_exec_requests " > %s%s%s dm_exec_requests DM_EXEC_REQUESTS

DM_EXEC_REQUESTS SQL SERVER

Appendix B

Transaction Log Column listing:

1	CurrentLSN	24	CHKPT End DB Version	46	PrepLogBegin LSN
2	Operation	25	Minimum LSN	47	PrepareTime
3	Context	26	Dirty Pages	48	Virtual Clock
4	Transaction ID		Oldest Replicated Begin	49	Previous Savepoint
5	Tag Bits	27	LSN	50	Savepoint Name
6	Log Record Fixed Length	28	Next Replicated End LSN	51	Rowbits First Bit
7	Log Record Length	29	Last Distributed End LSN	52	Rowbits Bit Count
8	PreviousLSN	30	Server UID	53	Rowbits Bit Value
9	Flag Bits	31	UID	54	Number of Locks
	AllocUnitID	32	SPID	55	Lock Information
11	AllocUnitName	33	BeginLogStatus	56	LSN Before Writes
12	Page ID	34	Begin Time	57	Pages Written
13	Slot ID	35	Transaction Name	58	Data Pages Delta
14	Previous Page LSN	36	Transaction SID	59	Reserved Pages Delta
15	PartionID	37	End Time	60	Used Pages Delta
16	RowFlags	38	Transaction Begin	61	Data Rows Delta
17	Num Elements	39	Replicated Records	62	Command Type
18	Offset in Row	40	Oldest Active LSN	63	Publication ID
19	Checkpoint Begin	41	Server Name	64	Article ID
20	CHKPT Begin DB Version	42	Database Name	65	Partial Status
21	MaxXDESID	43	Mark Name	66	Command
22	Num Transactions	44	Master XDESID	67	Byte Offset
23	Checkpoint End	45	Master DBID	68	New Value

69	Old Value	71	Rows Deleted	73	CI Table ID
70	New Split Page	72	Bytes Freed	74	CI Index ID
75	NewAllocationUnitID	85	Column Offset		Bulk allocation first IAM
76	FIlegroupID	86	Flags	95	Page ID
77	Meta Status	87	Text Size	96	Bulk allocated extent ids
78	File Status	88	Offset	97	RowLog Contents 0
79	File ID	89	Old Size	98	RowLog Contents 1
80	Physical Name	90	New Size	99	RowLog Contents 2
81	Logical Name	91	Description	100	RowLog Contents 3
82	Format LSN	92	Bulk allocated extent count	101	RowLog Contents 4
83	RowsetID	93	Bulk rowinsertID		
84	TextPtr	94	Bulk allocationunitID		

References

[1] Keith J. Jones, Richard Bejtlich, Curtis W. Rose. Real Digital Forensics, Addison-Wesley, 2006

[2] "MSDN Blog Pages" http://blogs.msdn.com/sqlserverstorageengine/default.aspx

[3] Microsoft Developer Network "MSDN" http://msdn2.microsoft.com/en-us/default.aspx

[4] SQL Server 2005 Books Online, http://msdn2.microsoft.com/en-us/library/ms130214.aspx

[5] Kalen Delaney. Inside SQL Server 2005 The Storage Engine, Microsoft Press, 2007

[6] Kalen Delaney and Jim Gray. Inside SQL Server 2000. Microsoft Press, 2001

[7] Brian Carrier. File System Forensic Analysis. Addison-Wesley, 2005

Last Updated: June 18th, 2018

Upcoming SANS Training

Click Here for a full list of all Upcoming SANS Events by Location

SANS Paris June 2018	Paris, FR	Jun 25, 2018 - Jun 30, 2018	Live Event
SANS Minneapolis 2018	Minneapolis, MNUS	Jun 25, 2018 - Jun 30, 2018	Live Event
SANS Vancouver 2018	Vancouver, BCCA	Jun 25, 2018 - Jun 30, 2018	Live Event
SANS London July 2018	London, GB	Jul 02, 2018 - Jul 07, 2018	Live Event
SANS Cyber Defence Singapore 2018	Singapore, SG	Jul 09, 2018 - Jul 14, 2018	Live Event
SANS Charlotte 2018	Charlotte, NCUS	Jul 09, 2018 - Jul 14, 2018	Live Event
SANSFIRE 2018	Washington, DCUS	Jul 14, 2018 - Jul 21, 2018	Live Event
SANS Cyber Defence Bangalore 2018	Bangalore, IN	Jul 16, 2018 - Jul 28, 2018	Live Event
SANS Pen Test Berlin 2018	Berlin, DE	Jul 23, 2018 - Jul 28, 2018	Live Event
SANS Riyadh July 2018	Riyadh, SA	Jul 28, 2018 - Aug 02, 2018	Live Event
Security Operations Summit & Training 2018	New Orleans, LAUS	Jul 30, 2018 - Aug 06, 2018	Live Event
SANS Pittsburgh 2018	Pittsburgh, PAUS	Jul 30, 2018 - Aug 04, 2018	Live Event
SANS San Antonio 2018	San Antonio, TXUS	Aug 06, 2018 - Aug 11, 2018	Live Event
SANS August Sydney 2018	Sydney, AU	Aug 06, 2018 - Aug 25, 2018	Live Event
SANS Boston Summer 2018	Boston, MAUS	Aug 06, 2018 - Aug 11, 2018	Live Event
Security Awareness Summit & Training 2018	Charleston, SCUS	Aug 06, 2018 - Aug 15, 2018	Live Event
SANS Hyderabad 2018	Hyderabad, IN	Aug 06, 2018 - Aug 11, 2018	Live Event
SANS New York City Summer 2018	New York City, NYUS	Aug 13, 2018 - Aug 18, 2018	Live Event
SANS Northern Virginia- Alexandria 2018	Alexandria, VAUS	Aug 13, 2018 - Aug 18, 2018	Live Event
SANS Krakow 2018	Krakow, PL	Aug 20, 2018 - Aug 25, 2018	Live Event
SANS Chicago 2018	Chicago, ILUS	Aug 20, 2018 - Aug 25, 2018	Live Event
Data Breach Summit & Training 2018	New York City, NYUS	Aug 20, 2018 - Aug 27, 2018	Live Event
SANS Prague 2018	Prague, CZ	Aug 20, 2018 - Aug 25, 2018	Live Event
SANS Virginia Beach 2018	Virginia Beach, VAUS	Aug 20, 2018 - Aug 31, 2018	Live Event
SANS San Francisco Summer 2018	San Francisco, CAUS	Aug 26, 2018 - Aug 31, 2018	Live Event
SANS Copenhagen August 2018	Copenhagen, DK	Aug 27, 2018 - Sep 01, 2018	Live Event
SANS SEC504 @ Bangalore 2018	Bangalore, IN	Aug 27, 2018 - Sep 01, 2018	Live Event
SANS Wellington 2018	Wellington, NZ	Sep 03, 2018 - Sep 08, 2018	Live Event
SANS Amsterdam September 2018	Amsterdam, NL	Sep 03, 2018 - Sep 08, 2018	Live Event
SANS Tokyo Autumn 2018	Tokyo, JP	Sep 03, 2018 - Sep 15, 2018	Live Event
SANS Tampa-Clearwater 2018	Tampa, FLUS	Sep 04, 2018 - Sep 09, 2018	Live Event
SANS MGT516 Beta One 2018	Arlington, VAUS	Sep 04, 2018 - Sep 08, 2018	Live Event
SANS Cyber Defence Canberra 2018	OnlineAU	Jun 25, 2018 - Jul 07, 2018	Live Event
SANS OnDemand	Books & MP3s OnlyUS	Anytime	Self Paced