Open Web Application Security Project

Web Application Firewall Bypassing – how to defeat the blue team

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STRUCTURE

- Motivation & Objective
- Introduction to Web Application Firewalls
- Bypassing Methods and Techniques
- Approach for Penetration Testers
- The Tool WAFNinja
- Results
- Conclusion

Motivation & Objective

MOTIVATION AND THESIS OBJECTIVE (I)
MOTIVATION

- Number of deployed Web Application Firewalls (WAFs) is increasing
- WAFs make a penetration test more difficult
- Attempting to bypass a WAF is an important aspect of a penetration test

MOTIVATION AND THESIS OBJECTIVE (II)
OBJECTIVE

Provide a practical approach for penetration testers which helps to ensure accurate results

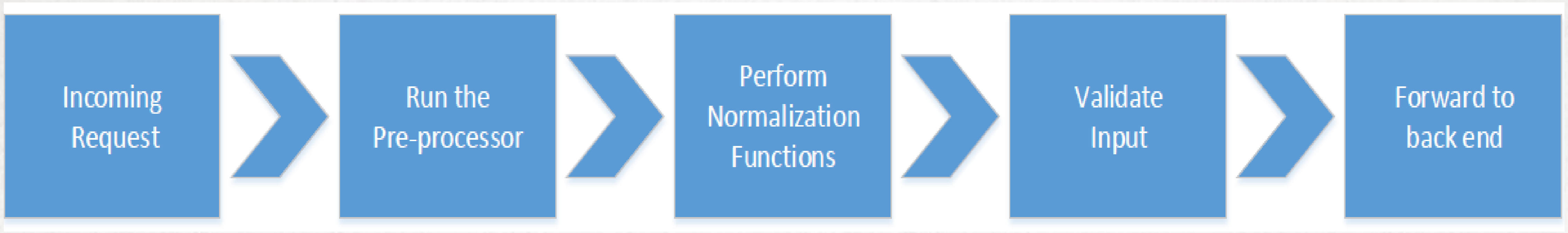
Introduction to Web Application Firewalls

INTRODUCTION TO WEB APPLICATION FIREWALLS (I)

OVERVIEW

- Protects a web application by adding a security layer
- Stands between a user and a web server
- Understands HTTP traffic better than traditional firewalls
- Checks for malicious traffic and blocks it

INTRODUCTION TO WEB APPLICATION FIREWALLS (IV)
FUNCTIONALITY



- Pre-processor:

  Decide wether a request will be processed further

- Normalization:

  Standardize user input

- Validate Input:

  Check user input against policies

INTRODUCTION TO WEB APPLICATION FIREWALLS (V)

NORMALIZATION FUNCTIONS

- Simplifies the writing of rules
- No Knowledge about different forms of input needed

compressWhitespace	converts whitespace chars to spaces
hexDecode	decodes a hex-encoded string
lowercase	converts characters to lowercase
urlDecode	decodes a URL-encoded string

INTRODUCTION TO WEB APPLICATION FIREWALLS (VI)

INPUT VALIDATION

- Security Models define how to enforce policies
- Policies consist of regular expressions
- Three Security Models:
  1. Positive Security Model
  2. Negative Security Model
  3. Hybrid Security Model

INTRODUCTION TO WEB APPLICATION FIREWALLS (VII)

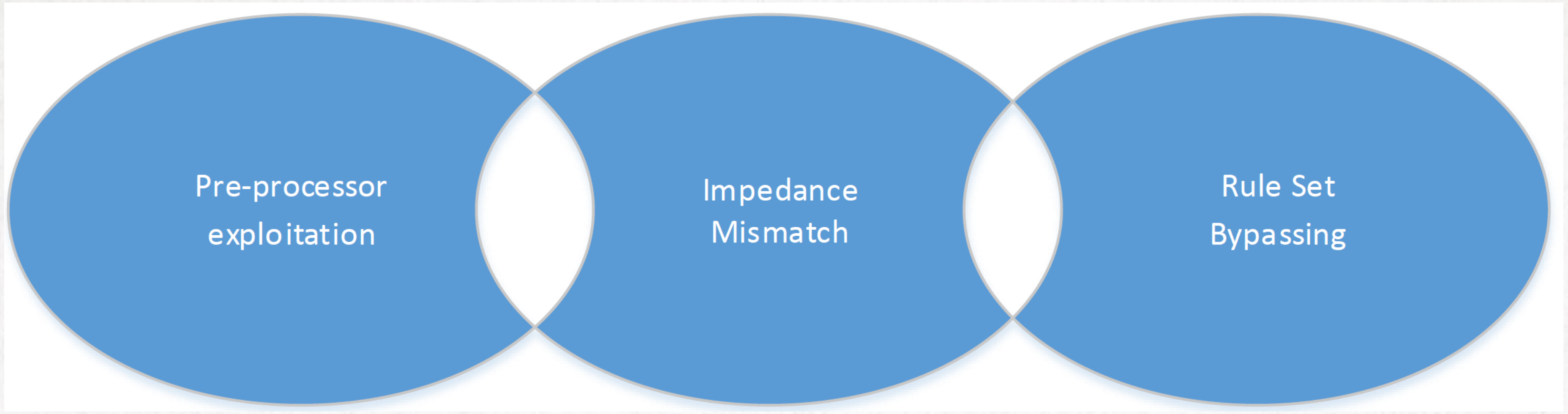
INPUT VALIDATION

Positive Security Model (Whitelist)	Negative Security Model (Blacklist)
Deny all but known good	Allow all but known bad
Prevents Zero-day Exploits	Shipped with WAF
More secure than blacklist	Fast adoption
Comprehensive understanding of application is needed	Little knowledge needed
Creating policies is a time-consuming process	Protect several applications
	Tends to false positives
	Resource-consuming

Bypassing Methods and Techniques

BYPASSING METHODS AND TECHNIQUES (I)

OVERVIEW



Pre-processor Exploitation:

Make WAF skip input validation

Impedance Mismatch:

WAF interprets input differently than back end

Rule Set Bypassing:

Use Payloads that are not detected by the WAF

Pre-processor Exploitation

BYPASSING METHODS AND TECHNIQUES (II)
BYPASSING PARAMETER VERIFICATION

- PHP removes whitespaces from parameter names or transforms them into underscores

```
http://www.website.com/products.php?%20productid=select 1,2,3
```

- ASP removes % character that is not followed by two hexadecimal digits

```
http://www.website.com/products.aspx?%productid=select 1,2,3
```

- A WAF which does not reject unknown parameters may be bypassed with this technique.

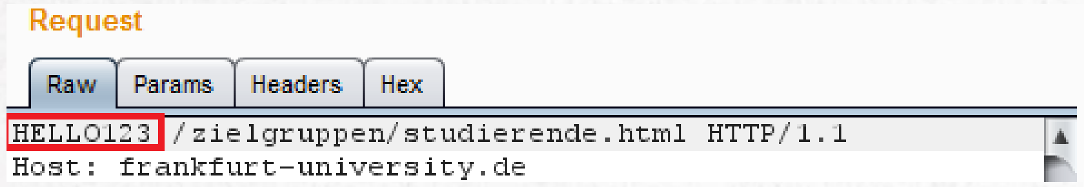
BYPASSING METHODS AND TECHNIQUES (III)
PRE-PROCESSOR EXPLOITATION EXAMPLE

X-* Headers

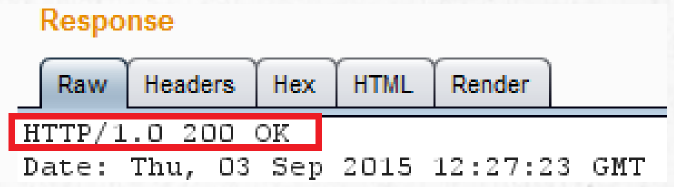
- WAF may be configured to trust certain internal IP Addresses
- Input validation is not applied on requests originating from these IPs
- If WAF retrieves these IPs from headers which can be changed by a user a bypass may occur
- A user is in control of the following HTTP Headers:
  - X-Originating-IP
  - X-Forwarded-For
  - X-Remote-IP
  - X-Remote-Addr

BYPASSING METHODS AND TECHNIQUES (IV)
MALFORMED HTTP METHOD

- Misconfigured web servers may accept malformed HTTP methods



```
HELLO123 /zielgruppen/studierende.html HTTP/1.1
Host: frankfurt-university.de
```



```
HTTP/1.0 200 OK
Date: Thu, 03 Sep 2015 12:27:23 GMT
```

- A WAF that only inspects GET and POST requests may be bypassed

BYPASSING METHODS AND TECHNIQUES (V)
OVERLOADING THE WAF

- A WAF may be configured to skip input validation if performance load is heavy
- Often applies to embedded WAFs
- Great deal of malicious requests can be sent with the chance that the WAF will overload and skip some requests

Impedance Mismatch

BYPASSING METHODS AND TECHNIQUES (VI)
HTTP PARAMETER POLLUTION

- Sending a number of parameters with the same name
- Technologies interpret this request

```
http://www.website.com/products/?productid=1&productid=2
```

differently:

Back end	Behavior	Processed
ASP.NET	Concatenate with comma	productid=1,2
JSP	First Occurrence	productid=1
PHP	Last Occurrence	productid=2

BYPASSING METHODS AND TECHNIQUES (VII)
IMPEDANCE MISMATCH EXAMPLE

The following payload

```
?productid=select 1,2,3 from table
```

can be divided:

```
?productid=select 1&productid=2,3 from table
```

- WAF sees two individual parameters and may not detect the payload
- ASP.NET back end concatenates both values

BYPASSING METHODS AND TECHNIQUES (VIII)
HTTP PARAMETER FRAGMENTATION

- Splitting subsequent code between different parameters
- Example query:

```
sql = "SELECT * FROM table WHERE uid = "+$_GET['uid']+" and pid = +$_GET[‘pid']“
```

- The following request:

```
http://www.website.com/index.php?uid=1+union/*&pid=*/select 1,2,3
```

would result in this SQL Query:

```
sql = "SELECT * FROM table WHERE uid = 1 union/* and pid = */select 1,2,3"
```

BYPASSING METHODS AND TECHNIQUES (IX)
DOUBLE URL ENCODING

- WAF normalizes URL encoded characters into ASCII text
- The WAF may be configured to decode characters only **once**
- Double URL Encoding a payload may result in a bypass

```
’s’ -> %73 -> %25%37%33
```

- The following payload contains a double URL encoded character

```
1 union %25%37%33elect 1,2,3
```

Rule Set Bypassing

BYPASSING METHODS AND TECHNIQUES (X)
BYPASS RULE SET

- Two methods:
  - Brute force by enumerating payloads
  - Reverse-engineer the WAFs rule set

APPROACH FOR PENETRATION TESTERS

APPROACH FOR PENETRATION TESTERS (I)

OVERVIEW

- Similar to the phases of a penetration test
- Divided into six phases, whereas Phase 0 may not always be possible

APPROACH FOR PENETRATION TESTERS(II)
PHASE 0

Identifying vulnerabilities with a disabled WAF

Objective: find security flaws in the application more easily

- ➢assessment of the security level of an application is more accurate

- Allows a more focused approach when the WAF is enabled
- May not be realizable in some penetration tests

APPROACH FOR PENETRATION TESTERS(III)
PHASE 1

Reconaissance

Objective: Gather information to get a good overview of the target

- Basis for the subsequent phases
- Gather information about:
  - web server
  - programming language
  - WAF & Security Model
  - Internal IP Addresses

APPROACH FOR PENETRATION TESTERS (IV)
PHASE 2

Attacking the pre-processor

Objective: make the WAF skip input validation

- Identify which parts of a HTTP request are inspected by the WAF to develop an exploit:
  1. Send individual requests that differ in the location of a payload
  2. Observe which requests are blocked
  3. Attempt to develop an exploit

APPROACH FOR PENETRATION TESTERS(V)
PHASE 3

Attempting an impedance mismatch

Objective: make the WAF interpret a request differently than the back end and therefore not detecting it

- Knowledge about back end technologies is needed

APPROACH FOR PENETRATION TESTERS(VI)
PHASE 4

Bypassing the rule set

Objective: find a payload that is not blocked by the WAFs rule set

1. Brute force by sending different payloads
2. Reverse-engineer the rule set in a trial and error approach:
    1. Send symbols and keywords that may be useful to craft a payload
    2. Observe which are blocked
    3. Attempt to develop an exploit based on the results of the previous steps

APPROACH FOR PENETRATION TESTERS(VII)

PHASE 5

Identifying miscellaneous vulnerabilities

Objective: find other vulnerabilities that can not be detected by the WAF

- Broken authentication mechanism
- Privilege escalation

APPROACH FOR PENETRATION TESTERS(VIII)

PHASE 6

Post assessment

Objective: Inform customer about the vulnerabilities

- Advise customer to fix the root cause of a vulnerability
- For the time being, the vulnerability should be virtually patched by adding specific rules to the WAF
- Explain that the WAF can help to mitigate a vulnerability, but can not thoroughly fix it

WAFNINJA

WAFNINJA (I)
OVERVIEW

- CLI Tool written in Python
- Automates parts of the approach
- Already used in several penetration tests
- Supports
  - HTTPS connections
  - GET and POST parameter
  - Usage of cookies

WAFNINJA (II)
MOST IMPORTANT FUNCTIONS

Fuzz	**Bypass**
• Reverse-engineer a WAFs rule set by sending different symbols and keywords • Analyzes the response of every request • Results are displayed in a clear and concise way • Fuzzing strings can be extended with the **insert-fuzz** function	• Brute forcing the WAF by enumerating payloads and sending them to the target • Analyzes the response of every request • Results are displayed in a clear and concise way • Payloads can be extended with the **insert-bypass** function

RESULTS

RESULTS (I)
OVERVIEW

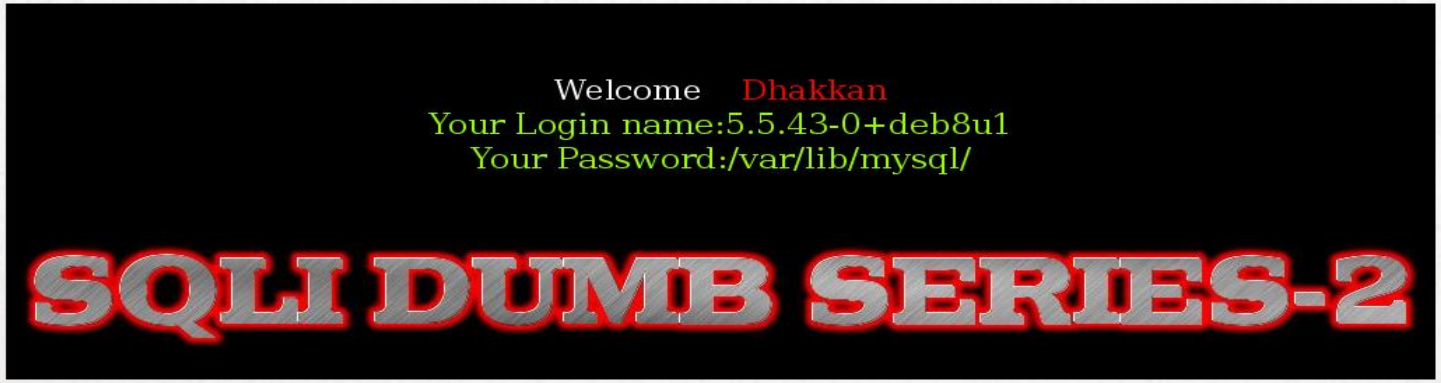
- Results of using WAFNinja to attempt to bypass three WAFs in a test environment
- Deployed WAFs used the standard configuration
- Two vulnerable web applications behind every WAF

RESULTS (II)
COMODO WAF

- Most intelligent rule set of the three tested WAFs
- SQL Injection payload found:

```
0 union/**/select 1,version(),@@datadir
```

- Disclosure of sensitive information:



```
Welcome    Dhakkan
Your Login name:5.5.43-0+deb8u1
Your Password:/var/lib/mysql/
```

RESULTS (III)
MODSECURITY WAF

- Highly restrictive rule set
- SQL Injection payload found:

```
1+uni%0Bon+se%0Blect+1,2,3
```

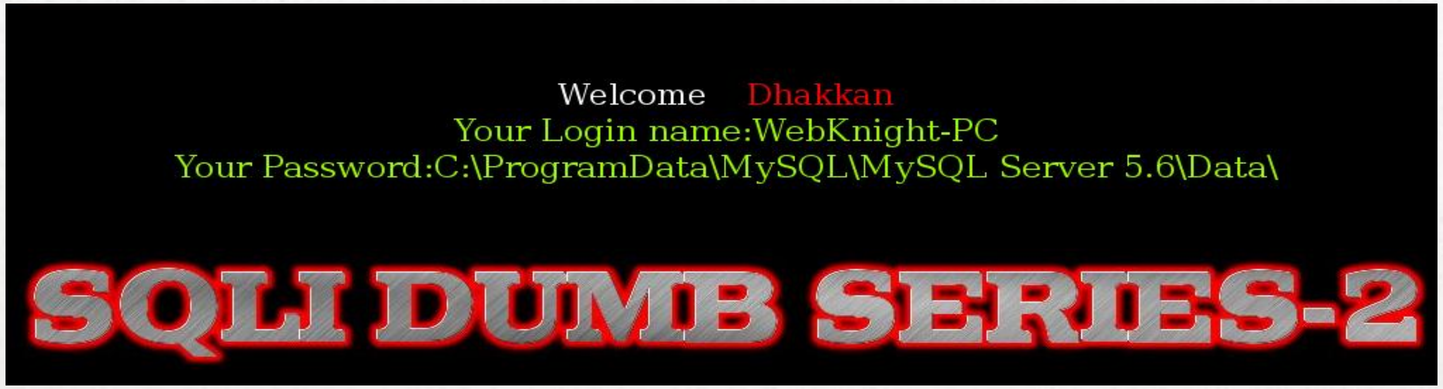
but was not processed by the back end

RESULTS (IV)
AQTRONIX WEBKNIGHT WAF

- Most vulnerable rule set of all three WAFs
- SQL Injection payload found:

```
0 union(select 1,@@hostname,@@datadir)
```

- Disclosure of sensitive information:



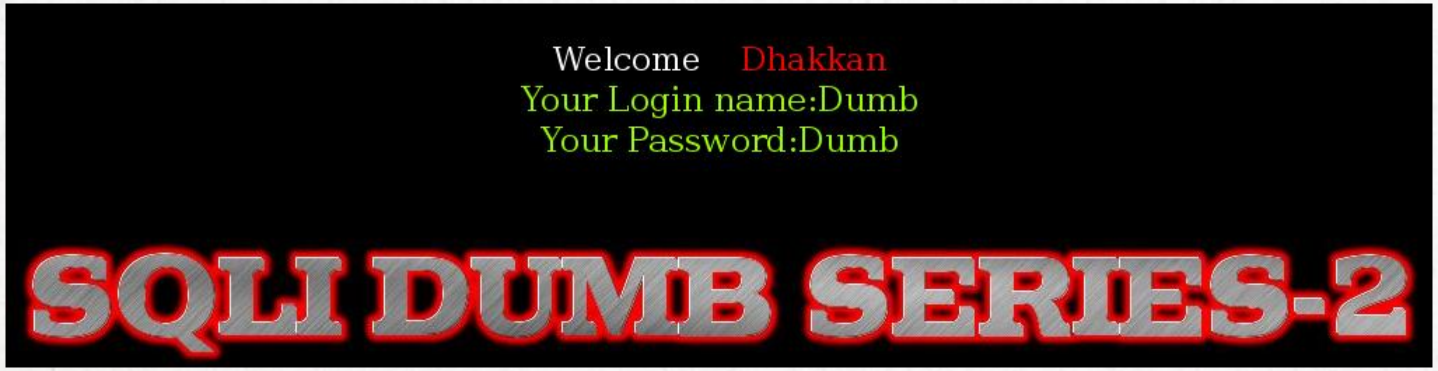
```
Welcome    Dhakkan
Your Login name:WebKnight-PC
Your Password:C:\ProgramData\MySQL\MySQL Server 5.6\Data\
```

RESULTS (V)
AQTRONIX WEBKNIGHT

- SQL Injection payload found:

```
0 union(select 1,username,password from(users))
```

- Disclosure of personal data:



```
Welcome    Dhakkan
Your Login name:Dumb
Your Password:Dumb
```

RESULTS (VI)
AQTRONIX WEBKNIGHT

- XSS payload found:

```
<img src=x onwheel=prompt(1)>
```

- “onwheel” replaced an old JavaScript event handler

CONCLUSION

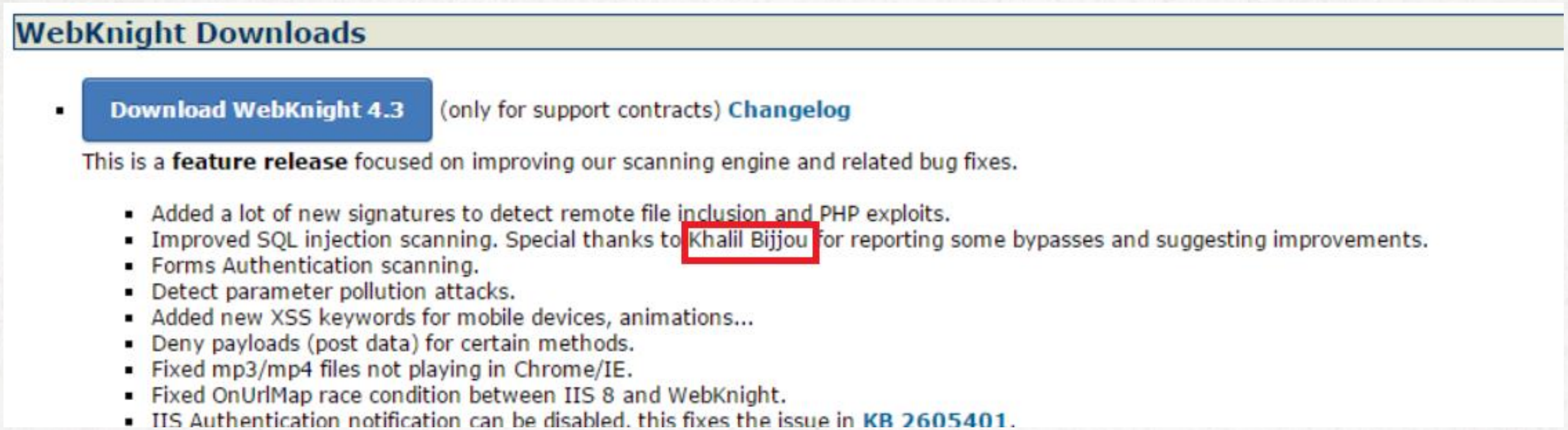
CONCLUSION (I)

- Different Bypass Methods and Techniques have been gathered and categorized
- Based on these techniques a practical approach is described
- A tool which facilitates this approach was developed
- The tool’s results contributed to finding several bypasses

CONCLUSION (II)

- The given approach can improve the accuracy of penetration test results
- The listing of bypassing techniques can be used by vendors to improve their WAFs
- WAF vulnerabilities found were reported to the particular WAF vendors
- Ultimately: WAFs make exploiting vulnerabilities more difficult, but do not guarantee that a security breach will not happen

CONCLUSION (III)



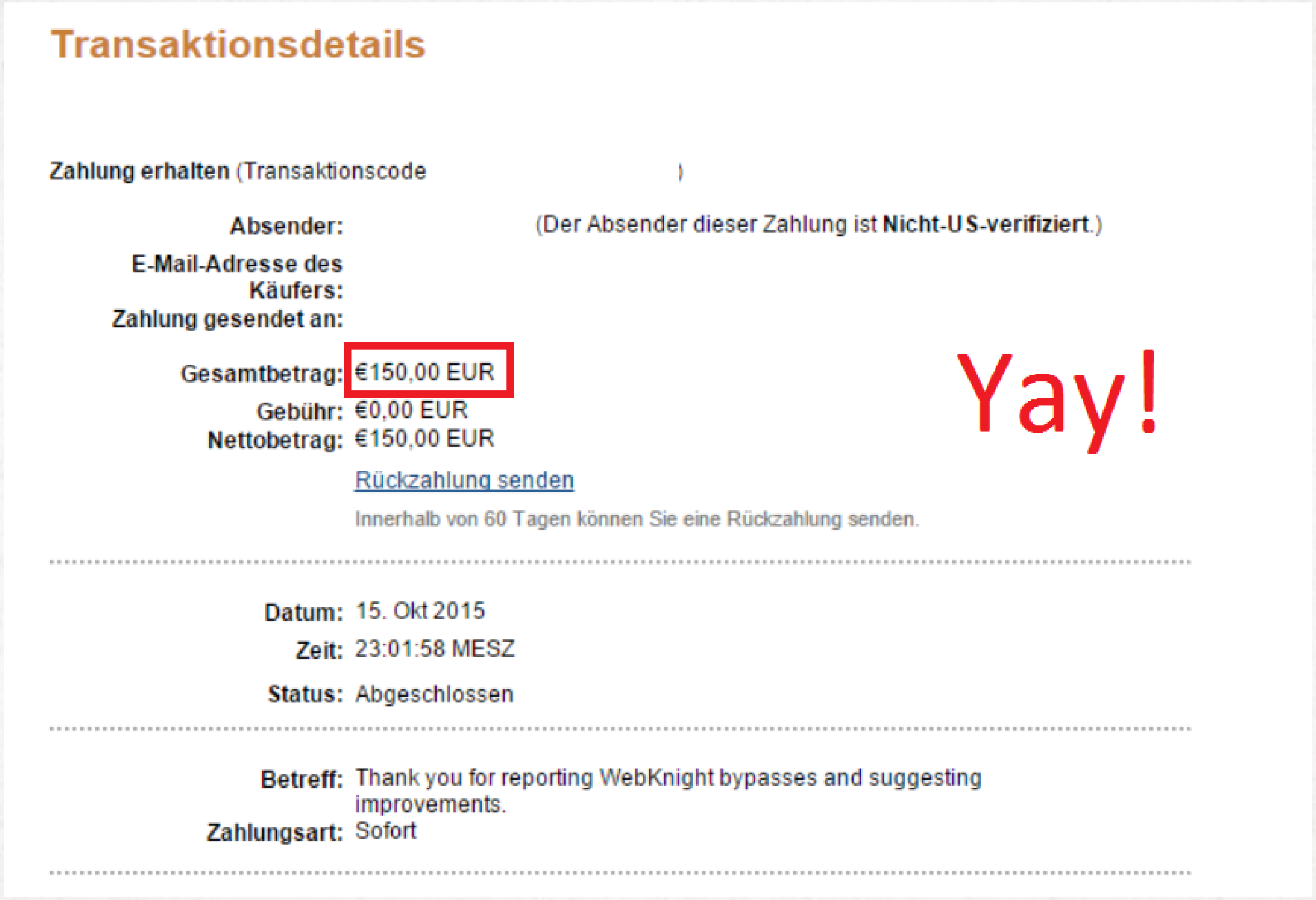
WebKnight Downloads

- Download WebKnight 4.3 (only for support contracts) Changelog

This is a **feature release** focused on improving our scanning engine and related bug fixes.

- Added a lot of new signatures to detect remote file inclusion and PHP exploits.
- Improved SQL injection scanning. Special thanks to Khalil Bijjou for reporting some bypasses and suggesting improvements.
- Forms Authentication scanning.
- Detect parameter pollution attacks.
- Added new XSS keywords for mobile devices, animations...
- Deny payloads (post data) for certain methods.
- Fixed mp3/mp4 files not playing in Chrome/IE.
- Fixed OnUrlMap race condition between IIS 8 and WebKnight.
- IIS Authentication notification can be disabled, this fixes the issue in KB 2605401.

CONCLUSION (III)



Transaktionsdetails

Zahlung erhalten (Transaktionscode)

Absender:	(Der Absender dieser Zahlung ist **Nicht-US-verifiziert**.)
E-Mail-Adresse des Käufers:	
Zahlung gesendet an:	
Gesamtbetrag:	€150,00 EUR
Gebühr:	€0,00 EUR
Nettobetrag:	€150,00 EUR
	Rückzahlung senden
	Innerhalb von 60 Tagen können Sie eine Rückzahlung senden.
Datum:	15. Okt 2015
Zeit:	23:01:58 MESZ
Status:	Abgeschlossen
Betreff:	Thank you for reporting WebKnight bypasses and suggesting improvements.
Zahlungsart:	Sofort

Yay!

THANK YOU FOR YOUR ATTENTION!

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