



**OWASP**

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
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# **Motivation & Objective**

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# 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
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# **MOTIVATION AND THESIS OBJECTIVE (II)**

## **OBJECTIVE**

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

# **Introduction to Web Application Firewalls**

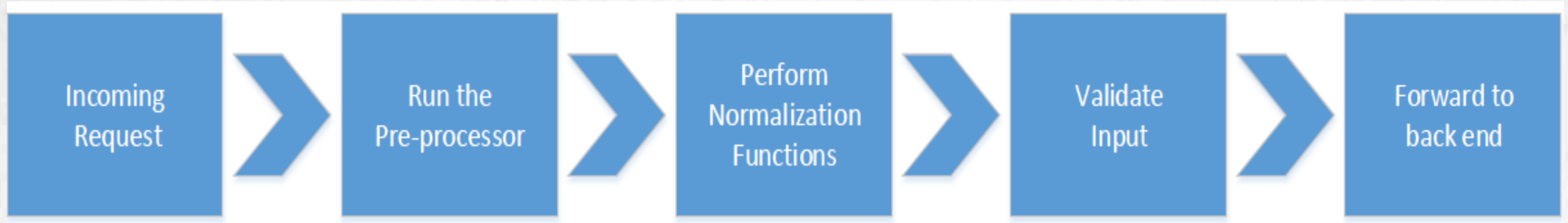
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# INTRODUCTION TO WEB APPLICATION FIREWALLS (I)

## 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
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# INTRODUCTION TO WEB APPLICATION FIREWALLS (IV) FUNCTIONALITY



- Pre-processor:

Decide whether 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

<b>compressWhitespace</b>	converts whitespace chars to spaces
<b>hexDecode</b>	decodes a hex-encoded string
<b>lowercase</b>	converts characters to lowercase
<b>urlDecode</b>	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
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# INTRODUCTION TO WEB APPLICATION FIREWALLS (VII)

## INPUT VALIDATION

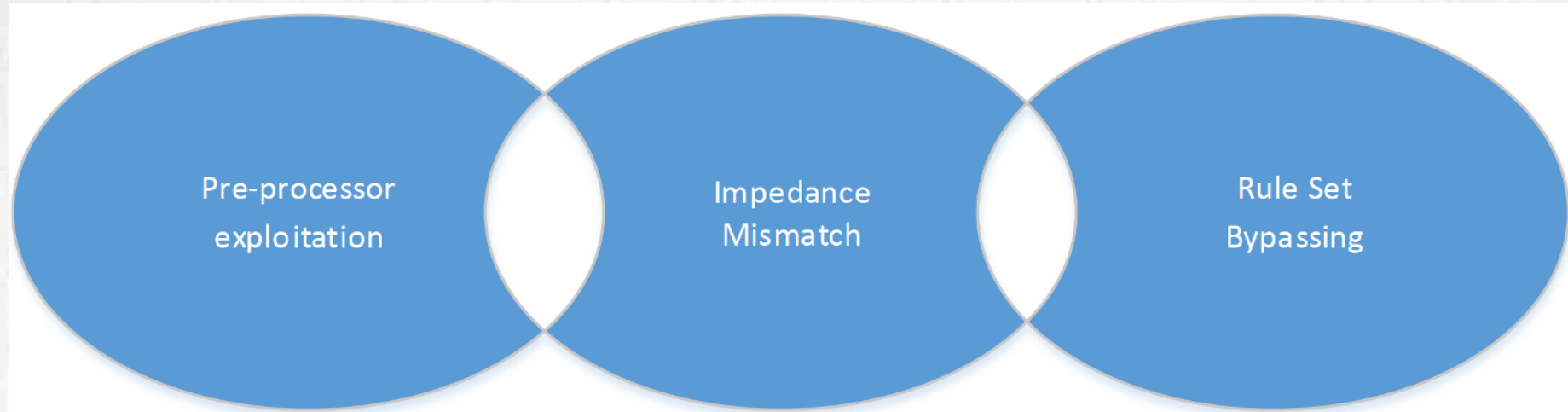
Positive Security Model (Whitelist)	Negative Security Model (Blacklist)
Deny all but known good	Allow all but known bad
Prevents Zero-day Exploits	Shipped with WAF
More secure than blacklist	Fast adoption
Comprehensive understanding of application is needed	Little knowledge needed
Creating policies is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

# **Bypassing Methods and Techniques**

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# 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**

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# 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**

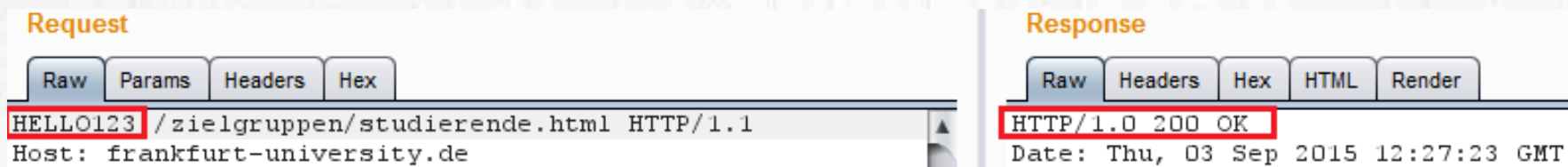
- WAF may be configured to trust certain internal IP Addresses
  - Input validation is not applied on requests originating from these IPs
  - If WAF retrieves these IPs from headers which can be changed by a user a bypass may occur
  - A user is in control of the following HTTP Headers:
    - X-Originating-IP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



The screenshot displays the 'Request' and 'Response' sections of a web browser's developer tools. In the 'Request' section, the 'Raw' tab is selected, showing the text 'HELLO123 /zielgruppen/studierende.html HTTP/1.1' with 'HELLO123' highlighted in a red box. Below this, the text 'Host: frankfurt-university.de' is visible. In the 'Response' section, the 'Raw' tab is selected, showing the text 'HTTP/1.0 200 OK' with 'HTTP/1.0 200 OK' highlighted in a red box. Below this, the text 'Date: Thu, 03 Sep 2015 12:27:23 GMT' is visible.

- 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
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# **Impedance Mismatch**

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# 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**

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# **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**

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# 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

### Reconnaissance

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
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# 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
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**WAFNINJA**

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# 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

- 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

### Bypass

- 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
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# 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/
```

**SQLI DUMB SERIES-2**



# 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\
```

**SQLI DUMB SERIES-2**

# 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
```

**SQLI DUMB SERIES-2**

# RESULTS (VI)

## AQTRONIX WEBKNIGHT

- XSS payload found:

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

- “onwheel” replaced an old JavaScript event handler

# CONCLUSION

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# 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
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## 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
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# 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

Yay!

[Rückzahlung senden](#)

Innerhalb von 60 Tagen können Sie eine Rückzahlung senden.

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**Datum:** 15. Okt 2015  
**Zeit:** 23:01:58 MESZ  
**Status:** Abgeschlossen

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**Betreff:** Thank you for reporting WebKnight bypasses and suggesting improvements.  
**Zahlungsart:** Sofort

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**THANK YOU FOR YOUR  
ATTENTION!**

E-Mail: [kbijjou@deloitte.de](mailto:kbijjou@deloitte.de)

Xing: Khalil Bijjou