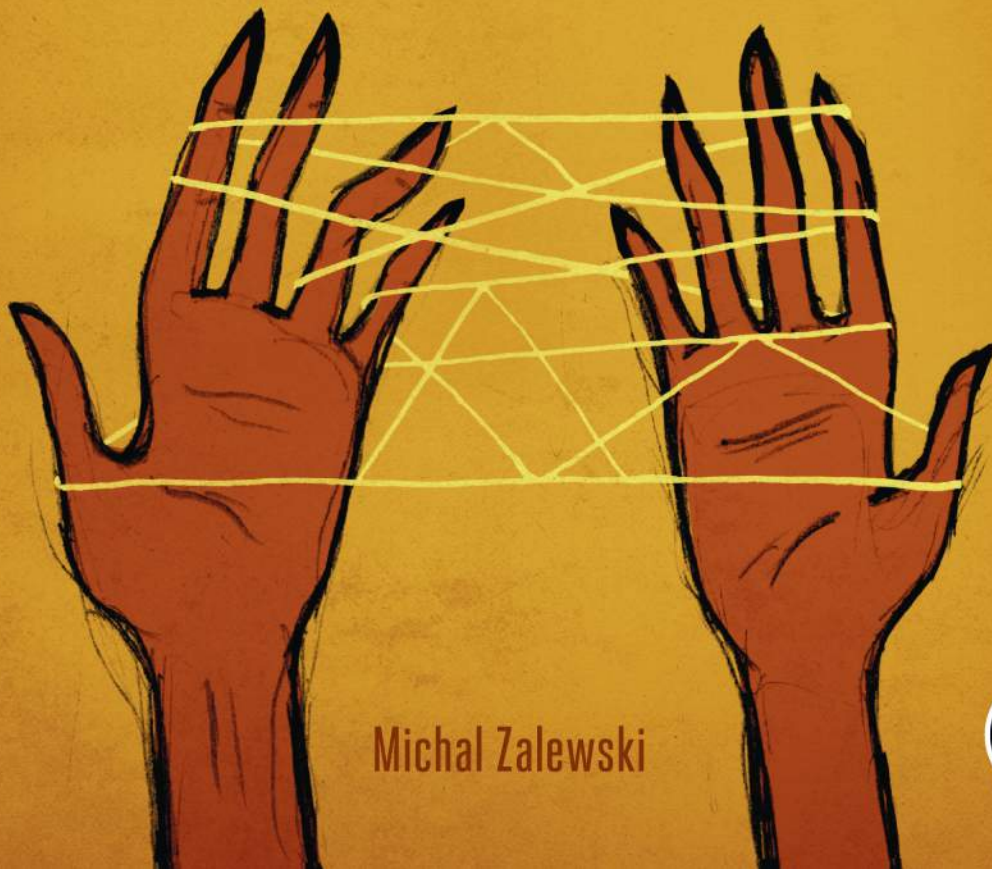


# *the* Tangled Web

*A Guide to Securing Modern  
Web Applications*



Michał Zalewski



# CONTENTS IN DETAIL

## PREFACE

xvii

Acknowledgments .....	xix
-----------------------	-----

## **1 SECURITY IN THE WORLD OF WEB APPLICATIONS 1**

Information Security in a Nutshell .....	1
Flirting with Formal Solutions .....	2
Enter Risk Management.....	4
Enlightenment Through Taxonomy .....	6
Toward Practical Approaches .....	7
A Brief History of the Web .....	8
Tales of the Stone Age: 1945 to 1994 .....	8
The First Browser Wars: 1995 to 1999 .....	10
The Boring Period: 2000 to 2003 .....	11
Web 2.0 and the Second Browser Wars: 2004 and Beyond .....	12
The Evolution of a Threat.....	14
The User as a Security Flaw.....	14
The Cloud, or the Joys of Communal Living.....	15
Nonconvergence of Visions.....	15
Cross-Browser Interactions: Synergy in Failure .....	16
The Breakdown of the Client-Server Divide .....	17

## **PART I: ANATOMY OF THE WEB 21**

### **2 IT STARTS WITH A URL 23**

Uniform Resource Locator Structure .....	24
Scheme Name .....	24
Indicator of a Hierarchical URL .....	25
Credentials to Access the Resource .....	26
Server Address .....	26
Server Port .....	27
Hierarchical File Path.....	27
Query String.....	28
Fragment ID.....	28
Putting It All Together Again .....	29
Reserved Characters and Percent Encoding .....	31
Handling of Non-US-ASCII Text.....	32
Common URL Schemes and Their Function.....	36
Browser-Supported, Document-Fetching Protocols .....	36
Protocols Claimed by Third-Party Applications and Plug-ins.....	36
Nonencapsulating Pseudo-Protocols.....	37
Encapsulating Pseudo-Protocols.....	37
Closing Note on Scheme Detection .....	38

Resolution of Relative URLs .....	38
Security Engineering Cheat Sheet.....	40
When Constructing Brand-New URLs Based on User Input.....	40
When Designing URL Input Filters .....	40
When Decoding Parameters Received Through URLs .....	40

### **3**

## **HYPertext TRAnsfer PROTOCOL** **41**

Basic Syntax of HTTP Traffic .....	42
The Consequences of Supporting HTTP/0.9 .....	44
Newline Handling Quirks.....	45
Proxy Requests.....	46
Resolution of Duplicate or Conflicting Headers.....	47
Semicolon-Delimited Header Values.....	48
Header Character Set and Encoding Schemes .....	49
Referer Header Behavior .....	51
HTTP Request Types .....	52
GET.....	52
POST.....	52
HEAD .....	53
OPTIONS.....	53
PUT .....	53
DELETE .....	53
TRACE .....	53
CONNECT .....	54
Other HTTP Methods .....	54
Server Response Codes.....	54
200–299: Success .....	54
300–399: Redirection and Other Status Messages.....	55
400–499: Client-Side Error .....	55
500–599: Server-Side Error .....	56
Consistency of HTTP Code Signaling .....	56
Keepalive Sessions .....	56
Chunked Data Transfers.....	57
Caching Behavior .....	58
HTTP Cookie Semantics.....	60
HTTP Authentication.....	62
Protocol-Level Encryption and Client Certificates .....	64
Extended Validation Certificates.....	65
Error-Handling Rules .....	65
Security Engineering Cheat Sheet.....	67
When Handling User-Controlled Filenames in Content-Disposition Headers .....	67
When Putting User Data in HTTP Cookies.....	67
When Sending User-Controlled Location Headers .....	67
When Sending User-Controlled Redirect Headers.....	67
When Constructing Other Types of User-Controlled Requests or Responses.....	67

<b>4</b>	<b>HYPertext MARKUP LANGUAGE</b>	<b>69</b>
Basic Concepts Behind HTML Documents .....	70	
Document Parsing Modes .....	71	
The Battle over Semantics .....	72	
Understanding HTML Parser Behavior .....	73	
Interactions Between Multiple Tags .....	74	
Explicit and Implicit Conditionals .....	75	
HTML Parsing Survival Tips .....	76	
Entity Encoding .....	76	
HTTP/HTML Integration Semantics .....	78	
Hyperlinking and Content Inclusion .....	79	
Plain Links .....	79	
Forms and Form-Triggered Requests .....	80	
Frames .....	82	
Type-Specific Content Inclusion .....	82	
A Note on Cross-Site Request Forgery .....	84	
Security Engineering Cheat Sheet .....	85	
Good Engineering Hygiene for All HTML Documents .....	85	
When Generating HTML Documents with Attacker-Controlled Bits .....	85	
When Converting HTML to Plaintext .....	85	
When Writing a Markup Filter for User Content .....	86	
<b>5</b>	<b>CASCADING STYLE SHEETS</b>	<b>87</b>
Basic CSS Syntax .....	88	
Property Definitions .....	89	
@ Directives and XBL Bindings .....	89	
Interactions with HTML .....	90	
Parser Resynchronization Risks .....	90	
Character Encoding .....	91	
Security Engineering Cheat Sheet .....	93	
When Loading Remote Stylesheets .....	93	
When Putting Attacker-Controlled Values into CSS .....	93	
When Filtering User-Supplied CSS .....	93	
When Allowing User-Specified Class Values on HTML Markup .....	93	
<b>6</b>	<b>BROWSER-SIDE SCRIPTS</b>	<b>95</b>
Basic Characteristics of JavaScript .....	96	
Script Processing Model .....	97	
Execution Ordering Control .....	100	
Code and Object Inspection Capabilities .....	101	
Modifying the Runtime Environment .....	102	
JavaScript Object Notation and Other Data Serializations .....	104	
E4X and Other Syntax Extensions .....	106	

Standard Object Hierarchy .....	107
The Document Object Model .....	109
Access to Other Documents .....	111
Script Character Encoding.....	112
Code Inclusion Modes and Nesting Risks .....	113
The Living Dead: Visual Basic .....	114
Security Engineering Cheat Sheet.....	115
When Loading Remote Scripts .....	115
When Parsing JSON Received from the Server .....	115
When Putting User-Supplied Data Inside JavaScript Blocks .....	115
When Interacting with Browser Objects on the Client Side .....	115
If You Want to Allow User-Controlled Scripts on Your Page .....	116

## **7 NON-HTML DOCUMENT TYPES 117**

Plaintext Files .....	117
Bitmap Images.....	118
Audio and Video .....	119
XML-Based Documents .....	119
Generic XML View .....	120
Scalable Vector Graphics.....	121
Mathematical Markup Language.....	122
XML User Interface Language.....	122
Wireless Markup Language.....	123
RSS and Atom Feeds .....	123
A Note on Nonrenderable File Types .....	124
Security Engineering Cheat Sheet.....	125
When Hosting XML-Based Document Formats .....	125
On All Non-HTML Document Types.....	125

## **8 CONTENT RENDERING WITH BROWSER PLUG-INS 127**

Invoking a Plug-in .....	128
The Perils of Plug-in Content-Type Handling .....	129
Document Rendering Helpers.....	130
Plug-in-Based Application Frameworks .....	131
Adobe Flash .....	132
Microsoft Silverlight .....	134
Sun Java .....	134
XML Browser Applications (XBAP) .....	135
ActiveX Controls.....	136
Living with Other Plug-ins .....	137
Security Engineering Cheat Sheet.....	138
When Serving Plug-in-Handled Files .....	138
When Embedding Plug-in-Handled Files.....	138
If You Want to Write a New Browser Plug-in or ActiveX Component .....	138

**9****CONTENT ISOLATION LOGIC****141**

Same-Origin Policy for the Document Object Model .....	142
document.domain .....	143
postMessage(...) .....	144
Interactions with Browser Credentials .....	145
Same-Origin Policy for XMLHttpRequest .....	146
Same-Origin Policy for Web Storage .....	148
Security Policy for Cookies .....	149
Impact of Cookies on the Same-Origin Policy .....	150
Problems with Domain Restrictions .....	151
The Unusual Danger of "localhost" .....	152
Cookies and "Legitimate" DNS Hijacking .....	153
Plug-in Security Rules .....	153
Adobe Flash .....	154
Microsoft Silverlight .....	157
Java .....	157
Coping with Ambiguous or Unexpected Origins .....	158
IP Addresses .....	158
Hostnames with Extra Periods .....	159
Non-Fully Qualified Hostnames .....	159
Local Files .....	159
Pseudo-URLs .....	161
Browser Extensions and UI .....	161
Other Uses of Origins .....	161
Security Engineering Cheat Sheet .....	162
Good Security Policy Hygiene for All Websites .....	162
When Relying on HTTP Cookies for Authentication .....	162
When Arranging Cross-Domain Communications in JavaScript .....	162
When Embedding Plug-in-Handled Active Content from Third Parties .....	162
When Hosting Your Own Plug-in-Executed Content .....	163
When Writing Browser Extensions .....	163

**10****ORIGIN INHERITANCE****165**

Origin Inheritance for about:blank .....	166
Inheritance for data: URLs .....	167
Inheritance for javascript: and vbscript: URLs .....	169
A Note on Restricted Pseudo-URLs .....	170
Security Engineering Cheat Sheet .....	172

**11****LIFE OUTSIDE SAME-ORIGIN RULES****173**

Window and Frame Interactions .....	174
Changing the Location of Existing Documents .....	174
Unsolicited Framing .....	178

Cross-Domain Content Inclusion .....	181
A Note on Cross-Origin Subresources.....	183
Privacy-Related Side Channels .....	184
Other SOP Loopholes and Their Uses .....	185
Security Engineering Cheat Sheet.....	186
Good Security Hygiene for All Websites .....	186
When Including Cross-Domain Resources.....	186
When Arranging Cross-Domain Communications in JavaScript .....	186

## **12 OTHER SECURITY BOUNDARIES** **187**

Navigation to Sensitive Schemes.....	188
Access to Internal Networks.....	189
Prohibited Ports.....	190
Limitations on Third-Party Cookies.....	192
Security Engineering Cheat Sheet.....	195
When Building Web Applications on Internal Networks.....	195
When Launching Non-HTTP Services, Particularly on Nonstandard Ports .....	195
When Using Third-Party Cookies for Gadgets or Sandboxed Content .....	195

## **13 CONTENT RECOGNITION MECHANISMS** **197**

Document Type Detection Logic.....	198
Malformed MIME Types.....	199
Special Content-Type Values.....	200
Unrecognized Content Type .....	202
Defensive Uses of Content-Disposition .....	203
Content Directives on Subresources .....	204
Downloaded Files and Other Non-HTTP Content .....	205
Character Set Handling .....	206
Byte Order Marks .....	208
Character Set Inheritance and Override.....	209
Markup-Controlled Charset on Subresources.....	209
Detection for Non-HTTP Files.....	210
Security Engineering Cheat Sheet.....	212
Good Security Practices for All Websites.....	212
When Generating Documents with Partly Attacker-Controlled Contents .....	212
When Hosting User-Generated Files .....	212

## **14 DEALING WITH ROGUE SCRIPTS** **213**

Denial-of-Service Attacks .....	214
Execution Time and Memory Use Restrictions .....	215
Connection Limits .....	216
Pop-Up Filtering .....	217
Dialog Use Restrictions.....	218
Window-Positioning and Appearance Problems.....	219
Timing Attacks on User Interfaces .....	222

Security Engineering Cheat Sheet.....	224
When Permitting User-Created <iframe> Gadgets on Your Site.....	224
When Building Security-Sensitive Uls .....	224

## **15**

### **EXTRINSIC SITE PRIVILEGES** **225**

Browser- and Plug-in-Managed Site Permissions .....	226
Hardcoded Domains .....	227
Form-Based Password Managers.....	227
Internet Explorer’s Zone Model .....	229
Mark of the Web and Zone.Identifier .....	231
Security Engineering Cheat Sheet.....	232
When Requesting Elevated Permissions from Within a Web Application .....	232
When Writing Plug-ins or Extensions That Recognize Privileged Origins.....	232

## **PART III: A GLIMPSE OF THINGS TO COME** **233**

### **16**

#### **NEW AND UPCOMING SECURITY FEATURES** **235**

Security Model Extension Frameworks .....	236
Cross-Domain Requests .....	236
XDomainRequest .....	239
Other Uses of the Origin Header .....	240
Security Model Restriction Frameworks .....	241
Content Security Policy.....	242
Sandboxed Frames .....	245
Strict Transport Security.....	248
Private Browsing Modes.....	249
Other Developments .....	250
In-Browser HTML Sanitizers.....	250
XSS Filtering .....	251
Security Engineering Cheat Sheet.....	253

### **17**

#### **OTHER BROWSER MECHANISMS OF NOTE** **255**

URL- and Protocol-Level Proposals .....	256
Content-Level Features.....	258
I/O Interfaces .....	259

### **18**

#### **COMMON WEB VULNERABILITIES** **261**

Vulnerabilities Specific to Web Applications.....	262
Problems to Keep in Mind in Web Application Design.....	263
Common Problems Unique to Server-Side Code .....	265



<b>EPILOGUE</b>	<b>267</b>
<b>NOTES</b>	<b>269</b>
<b>INDEX</b>	<b>273</b>