

Deconstructing ColdFusion

LASCON
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VERACODE

Hi

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Previously

- Technical Manager at Symantec (through acquisition)
- Technical Director and Consultant at @stake
- Security Researcher/Electrical Engineer at NSA

Industry Involvement

- Frequent speaker at security conferences (BlackHat, OWASP, RSA, etc.)
- Contributor to Common Weakness Enumeration (CWE), CWE/SANS Top 25 Most Dangerous Software Errors, WASC Security Statistics Project, and others
- Advisory board member for SOURCE Conferences (Boston and Barcelona)
- Developed @stake WebProxy

Motivations

- Few resources available on securing or testing ColdFusion apps
 - ColdFusion 8 developer security guidelines from 2007
http://www.adobe.com/devnet/coldfusion/articles/dev_security_coldfusion_security_cf8.pdf
 - “Securing Applications” section of ColdFusion 9 developer guide is similar, almost entirely about authentication methods
http://help.adobe.com/en_US/ColdFusion/9.0/Developing/coldfusion_9_dev.pdf
 - OWASP ColdFusion ESAPI started May 2009, abandoned (?) June 2009
<http://code.google.com/p/owasp-esapi-coldfusion/source/list>
 - EUsec presentation from 2006 focused mostly on the infrastructure footprint and deployment issues (admin interfaces, privilege levels, etc.)
<http://eusecwest.com/esw06/esw06-davis.pdf>
- We were developing ColdFusion support for our binary analysis service, so we were doing the research anyway
- No platform 0-days here; this is all about **vulnerabilities in custom apps**

Agenda

- ColdFusion Background and History
- Platform Architecture and CFML Crash Course
- Finding Vulnerabilities in ColdFusion Applications
- ColdFusion Behind the Curtain (if time permits)

ColdFusion Background and History

ColdFusion History

- Originally released in 1995 by Allaire
 - Motivation: make it easier to connect simple HTML pages to a database
 - Initially Windows only with built-in web server
- Migration to J2EE with ColdFusion 6 in 2002
 - Everything compiled to Java classes before being run
 - Apps can be bundled up as WARs/EARs, including admin interface if desired
 - Bundled with JRun
- Latest version is ColdFusion 9 released in 2009
 - Most recent features focus on integration with other technologies, e.g. Flash, Flex, AIR, Exchange, MS Office, etc.

Historical Vulnerabilities

- In the recent past
 - CVE-2010-2861: Unauthenticated directory traversal in Administrative interface
 - CVE-2009-3467 and CVE-2010-1293: Unspecified XSS vulnerabilities
 - CVE-2009-1876: Unspecified double-encoded null character infoleak
- Lots of XSS in sample apps, administrator UI, error pages
- Source code disclosure (canonicalization issues, sample apps)
- Authorization vulnerabilities related to administrative UI
- Prior to ColdFusion 6 (Allaire/Macromedia days)
 - Arbitrary file retrieval
 - XOR used to encrypt passwords
 - Predictable session identifiers (may have been sequential, IIRC)
 - Various DoS conditions and buffer overflows

Who Uses ColdFusion Anyway?

- Lots of people, believe it or not. Let's start by asking Google...

| Search Term | Hits |
|----------------|--------------------|
| ext:asp | 1,110,000,000 |
| ext:aspx | 1,320,000,000 |
| ext:cfm | 213,000,000 |
| ext:jsp | 556,000,000 |
| ext:php | 6,530,000,000 |
| ext:pl | 598,000,000 |
| ext:py | 8,210,000 |
| ext:rb | 372,000 |

Source: Google, October 25, 2010

Who Uses ColdFusion Anyway?

- “More than **770,000 developers** at over **12,000 companies** worldwide rely on Adobe® ColdFusion® software to rapidly build and deploy Internet applications. And with more than **125,000 ColdFusion servers** deployed, ColdFusion is one of the most widely adopted web technologies in the industry.”



Bank of America



citi



Smithsonian

eBay



PGA

BT

CISCO

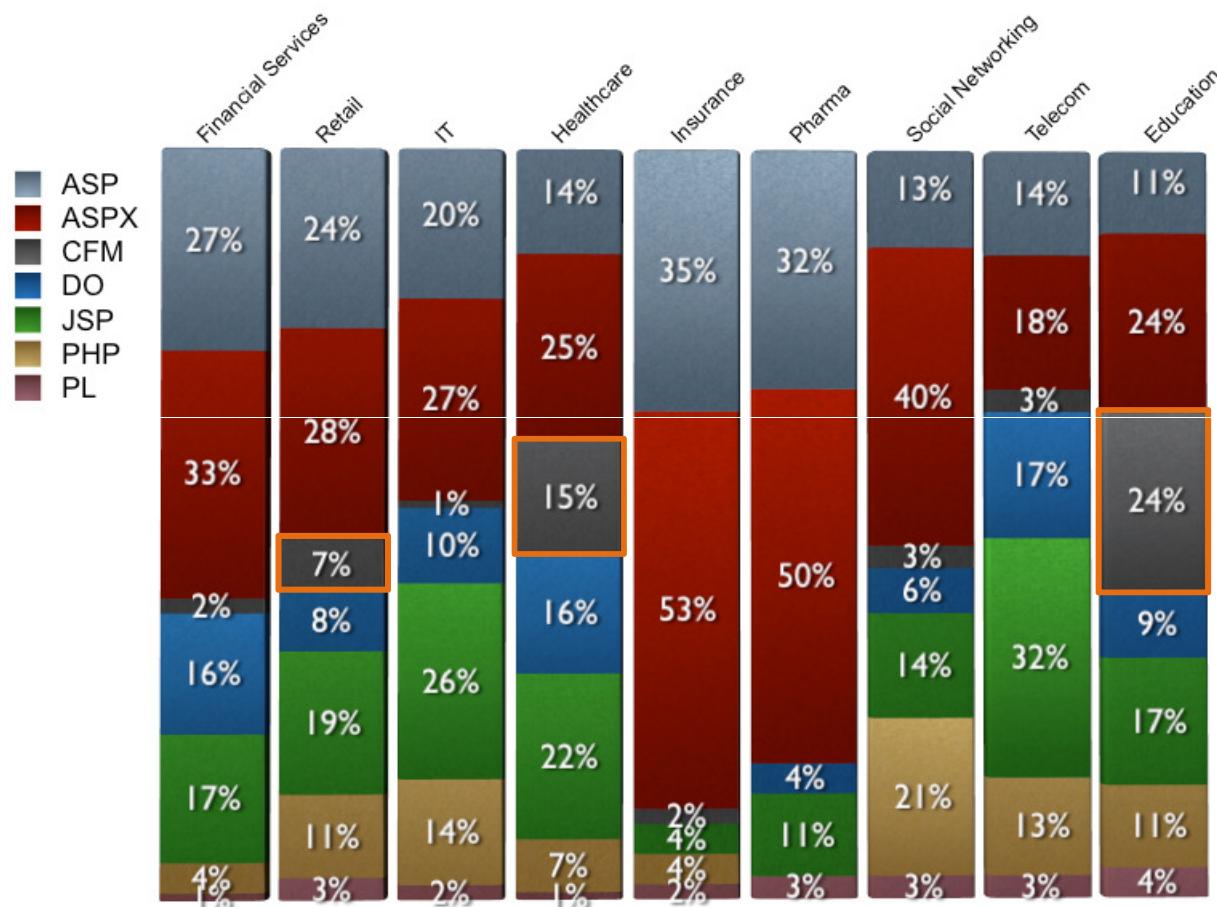


verizon

BOEING



ColdFusion Prevalence by Vertical



Source: WhiteHat Website Security Statistics Report, 9th Edition, May 2010

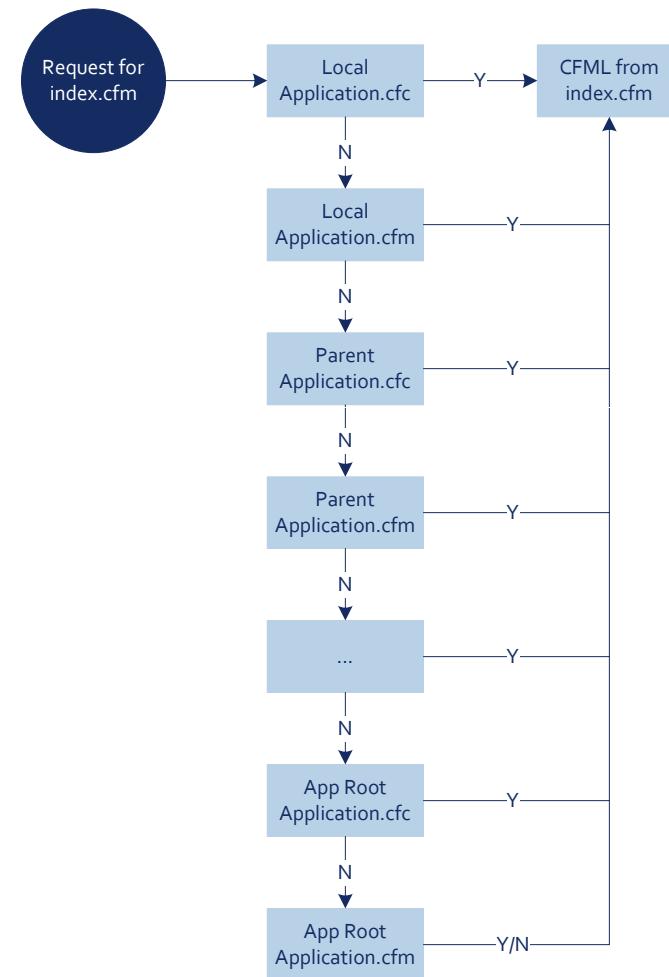
Platform Architecture and CFML Crash Course

CFML Building Blocks

- Pages
 - Main entry points of a CF application
 - Similar to an HTML page (or PHP, JSP, etc.) except using CFML tags
 - .cfm extension
- Components
 - Contain reusable functions / variables for use by other code
 - Written entirely in CFML
 - .cfc extension
- Functions (UDFs)
 - Defined inside components or pages
 - Called using CFINVOKE or inside a CFSCRIPT block/expression
 - Can be exposed as an entry point inside components

CFML Page Lifecycle, Part I

- When a page is requested, search for (and execute) Application.cfc or Application.cfm first
- Application.cfm is a plain old CFML file, while Application.cfc defines hooks into application events
- Common uses for this mechanism:
 - Login management
 - Centralized data validation
 - Messing with session variables
 - Error handling

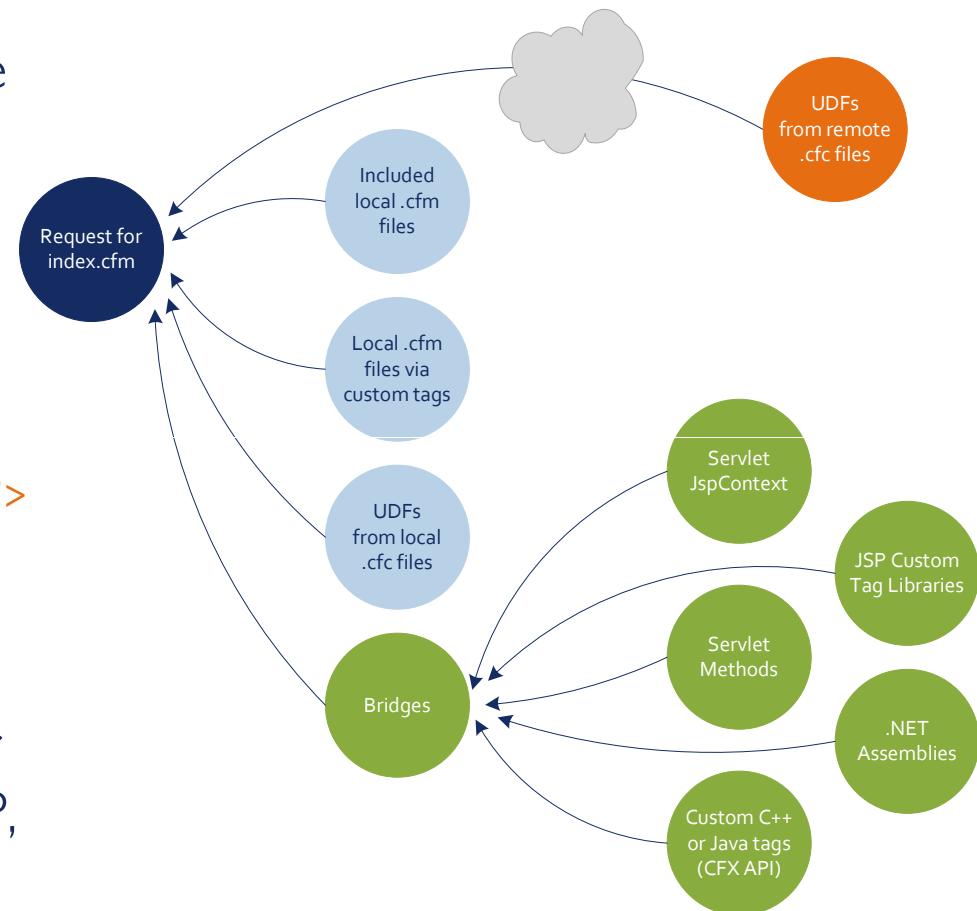


Inside Application.cfc

- **onApplicationStart**: application start (can access request variables)
- **onApplicationEnd**: application timeout/server shutdown
- **onSessionStart**: new session (can access request variables)
- **onSessionEnd**: session ends
- **onRequestStart**: called before every request (can access request variables)
- **onRequest**: called after onRequestStart code ends (can access request variables)
- **onRequestEnd**: called after request has been processed (can access request variables)
- **onMissingTemplate**: called when an unknown page has been requested (can access request variables)
- **onError**: when an uncaught exception occurs (can access request variables sometimes; check Event value)

CFML Page Lifecycle, Part 2

- A single page can include code from many different locations
- Custom tags are similar to local includes, but with different dataflow behavior
 - `<cf_foo>` is kind of like `<cfinclude template="foo.cfm">` except that changes made to variables are not visible in the calling page
- There are also built-in tags for interacting with remote HTTP, FTP, LDAP, SMTP, and POP servers



Variables are Dynamically Scoped

- Silos of global variables named “scopes” can be confusing
- Variable accesses can be fully-qualified (prefixed with scope name) or not qualified at all

```
<cfoutput>#foo#</cfoutput>  
<cfoutput>#URL.foo#</cfoutput>
```

- The unqualified scope can be temporarily “enhanced” with the results of a query row or loop iteration, e.g.

```
<cfquery name="qry" datasource="myDataSource">  
    SELECT col1, col2, col3 FROM myTable  
</cfquery>  
<cfoutput query="qry">#col1#, #col2#, #col3#</cfoutput>  
<cfoutput query="qry">#qry.col1#, #qry.col2#, #qry.col3#</cfoutput>
```

- Output without iteration is also possible:

```
<cfoutput> #qry.col1#, #qry.col2#, #qry.col3# </cfoutput>
```

Variable Scopes

| Scope | Description |
|-------------|--|
| Variables | the variable binding stack local to the current page |
| Application | global to every page in an app; set in application.cfc |
| Arguments | arguments to a function (may be tainted if called by a remote UDF) |
| Attributes | used to pass data to .cfm custom tag pages/threads |
| Caller | used within custom tags; reference to the calling page's Variables scope |
| Request | persistent across all code for the lifetime of the request; useful within custom tags and cfincluded pages |
| This | struct/component "member variables" |
| ThisTag | analogous to Request scope for custom tag pages |
| URL | parameters present in HTTP query string |
| Form | parameters present in HTTP POST body |
| Cookie | HTTP request cookies |
| CGI | CGI variables, some server-defined and some tainted |
| Session | persistent across a single site visit |
| Client | client-specific persistent storage; outlasts session variables |

Variable “Types” in ColdFusion

- The CF type system hasn't changed significantly since the 90s
- Implicit conversions to/from strings are the norm
- Instead of type checks, validation often done with pattern matches:
 - CFPARAM and CFARGUMENT “type” attributes
 - `<cfparam name="phoneno" type="telephone">` will throw an exception if “phoneno” is set and is not formatted as a standard US/NANPA phone number
 - Types “boolean”, “creditcard”, “date”, “time”, “eurodate”, “euertime”, “email”, “float”, “numeric”, “guid”, “integer”, “range”, “regex”, “ssn”, “telephone”, “URL”, “uuid”, “usdate”, “variablename”, “xml”, “zipcode” all check the string representation of the variable against regexes
 - Limited type checks are possible: “array”, “query”, “struct”, and “string”
- Numerous opaque types reused among contexts
 - Example: queries are used for database queries, directory iteration, ldap queries, http/ftp requests, and others

CF Expressions

- Automatic interpolation with #-expressions inside cfoutput and attributes:
 - `<cfoutput>#URL.foo#</cfoutput>`
 - `<cfloop query = "MyQuery" startRow = "#Start#" endRow = "#End#">`
`<cfoutput>#MyQuery.MyColName#</cfoutput>
`
`</cfloop>`
- Dynamic scoping can hinder analysis
 - `<cfset foo="bar">` vs. `<cfset "#foo#"="#bar#">`
 - `SetVariable("foo", "bar")` vs. `SetVariable(foo, bar)`
- Dynamic evaluation functions
 - `Evaluate()` and `PrecisionEvaluate()`
 - `IIF()`
 - `DE()` – used in conjunction with the other two

Finding Vulnerabilities in ColdFusion Applications

Spot the Tainted Data

- URL.any_variable
- FORM.any_variable
- COOKIE.any_variable
- FLASH.any_variable
- CGI.some_variables
 - e.g. PATH_INFO, QUERY_STRING, CONTENT_TYPE, CONTENT_LENGTH, HTTP_REFERER, HTTP_USER_AGENT, etc.
 - More on this later
- SESSION.some_variables
 - Depends on application logic
- CLIENT.any_variable
 - Only when client variables are enabled and storage is cookie-based
- CFFUNCTION arguments, when access="remote"

XSS? No Problem, scriptProtect to the Rescue!

- Using scriptProtect attribute
 - Replaces blacklisted tags such as <script>, <object>, etc. with <InvalidTag> when rendering user-supplied input
 - Doesn't block injection, aside from the most basic attack strings
- Example
 - `<cfapplication scriptProtect="all">`
`<cfoutput>You typed #URL.foo#</cfoutput>`
 - Requesting page with `?foo=<script>alert("foo")</script>` will return
`You typed <InvalidTag>alert("foo")</script>`
- Trivial to circumvent
 - One of many possibilities: requesting page with
`?foo=`
will happily execute the alert() call
 - Other regexes can be added to the blacklist, but it's still a blacklist (look for neo-security.xml if you insist)

I Also Have These Great Encoding Functions

- HTMLEditFormat() and HTMLCodeFormat() don't perform sufficient HTML encoding
 - They only encode <, >, ", and &
 - Ineffective for unquoted or single-quoted tag attributes, or within script blocks
 -
 -
 - <script>#HTMLEditFormat(URL.foo)#</script>
 - <script>var x='#HTMLEditFormat(URL.foo)#';</script>
 - etc.
 - XMLFormat() encodes single quotes, but still won't prevent XSS in all situations, e.g. inside Javascript or CSS blocks
- Contextual encoding? Have to roll your own...

No Problem, I'll Just Whitelist!

- This should work, right?
 - <cfoutput>#int(URL.count)#</cfoutput>
 - <cfset safenum=NumberFormat(FORM.bar)>
 - <cfoutput>#JavaCast("boolean", URL.booly)#</cfoutput>
- Default error page
 - scriptProtect is enabled on the default error page, but we already saw how (in)effective that is

The following information is meant for the website developer for debugging purposes.

Error Occurred While Processing Request

The value foo cannot be converted to a number.

Resources:

- Enable Robust Exception Information to provide greater detail about the source of errors. In the Administrator, click Debugging & Logging > Debug Output Settings, and select the Robust Exception Information option.
- Check the [ColdFusion documentation](#) to verify that you are using the correct syntax.
- Search the [Knowledge Base](#) to find a solution to your problem.

Browser Mozilla/5.0 (Windows; U; Windows NT 6.1; en-US; rv:1.9.2.3)
Gecko/20100401 Firefox/3.6.3 (.NET CLR 3.5.30729)

Remote Address 10.0.5.220

Referrer

Date/Time 24-May-10 02:36 PM

What If I Use a Custom Error Page?

- Avoid XSS risks in the default error page by defining your own custom error page

```
<cferror template="errorhandler.cfm" type="request">
```

Don't use #error.diagnostics# or #error.message# in your error page!

- Exception handling also works

```
<cftry>
  <cfoutput>#int(URL.count)#</cfoutput>
  <cfcatch>Exception caught!</cfcatch>
</cftry>
```

Don't output #cfcatch.message# in your catch block without properly encoding it first!

Common SQL Injection Mistakes

- Using CFQUERY without CFQUERYPARAM
(also CFSTOREDPROC without CFPROCPARAM)

```
<cfquery name="getContent" dataSource="myData">
    SELECT * FROM pages WHERE pageID = #Page_ID# OR
    title = '#Title_Search#'</cfquery>
```

- #Title_Search# is not injectable; CF will automatically escape single quotes for expressions inside the CFQUERY tag
- #Page_ID# is still injectable because it's not quoted
- Using CFQUERYPARAM

```
<cfquery name="getContent" dataSource="myData">
    SELECT * FROM pages WHERE pageID =
    <cfqueryparam value="#Page_ID#" cfsqltype="cf_sql_integer"></cfquery>
```

(For unknown reasons, cfsqltype is an *optional* attribute)

Other OWASP Top Ten Vulnerabilities

- We won't waste time rehashing all of the common web vulnerabilities
 - Of course you can have CSRF, insecure cryptographic storage, broken authentication/authorization, etc. in a ColdFusion app
 - Nothing unique enough to warrant discussion here
- Here are some tags to watch out for; it should be obvious why they are dangerous if not properly restricted
 - <cffile>
 - <cfdirectory>
 - <cfexecute>
 - <cfregistry>
 - <cfobject>
 - <cfinclude>

Directly Invoking UDFs

- Every method in a .cfc file is a potential entry point, e.g.
<http://example.com/foo.cfc?method=xyzzy&arga=vala&argb=valb>
- This URL will invoke method xyzzy on an anonymous instance of component foo.cfc, with arguments arga="vala" and argb="valb" (also valid with POST variables, although method must be passed in the query string)
 - If method doesn't exist, onMissingMethod is called
 - If method isn't specified, then the request gets redirected to CFIDE/componentutils/cfcexplorer.cfc
 - Rules for application.cfc and application.cfm still apply
- In a source code review, look for sensitive functionality implemented as UDFs, with the access attribute set to "remote"
e.g. `<cffunction name="ListCategories" access="remote" returntype="query">`

Search Order for Unscoped Variables

- If you use a variable name without a scope prefix, ColdFusion checks the scopes in the following order to find the variable:

| | |
|---|------------|
| 1. Local (function-local, UDFs and CFCs only) | 7. CGI |
| 2. Arguments | 8. Cffile |
| 3. Thread local (inside threads only) | 9. URL |
| 4. Query (not a true scope; variables in query loops) | 10. Form |
| 5. Thread | 11. Cookie |
| 6. Variables | 12. Client |

- For example, in applications with sloppy variable naming, you can almost always override POST (Form) parameters with GET (URL) parameters

Exploiting Unscoped Variables

- Consider this logic to process a user login (yes, it's contrived)

```
<cfif AuthenticateUser(FORM.username, FORM.password) and
    IsAdministrator(FORM.username)>
    <cfset Client.admin = "true">
<cfelse>
    <cfset Client.admin = "false">
</cfif>
```

- Other pages check whether the admin variable is true before performing restricted actions

```
<cfif admin eq "true">
    Put privileged functionality here!
<cfelse>
    Sorry, only admins can access this!
</cfif>
```

- Putting `?admin=true` in the URL will bypass this check because URL variables precede Client variables in the search order
- Compare reads/writes of variables to identify scoping inconsistencies

Exploiting User-Supplied Variable Scope

- Code similar to the following

```
<cfloop item="x" collection="#URL#">
  <cfscript>SetVariable(x, Evaluate("URL." & x));</cfscript>
</cfloop>
...
<cfif Client.username eq "admin">
  Put privileged functionality here!
<cfelse>
  Sorry, only admins can access this!
</cfif>
```

- Attack by putting ?client.username=admin in the URL
- Beware of any variable assignments with user-supplied LHS!
e.g. <cfset "#URL.varname#" = "#URL.varvalue#">

Undefined Variables

- Similarly, ensure that variables are always initialized properly
- CFPARAM's "default" attribute only sets a variable if it's not set already; use CFSET or an assignment inside cfscript
- Assume undefined, unqualified variables are filled with request data!
- It's common to see code like:

```
<cfparam name="pagenum" default="1">
<cfoutput>
    Now showing page #pagenum#.
</cfoutput>
```

- This is exploitable; GET and POST variables will override pagenum

Environment Variables

- Legitimate variables in the CGI scope can be manipulated and in some cases overridden via HTTP headers
- For example:

```
GET /index.cfm HTTP/1.0
Host: example.com
```

The CF expression #CGI.HTTP_HOST# will contain “example.com”

```
GET /index.cfm HTTP/1.0
HTTP_HOST: evil.com
Host: example.com
```

The CF expression #CGI.HTTP_HOST# will contain “evil.com”

- You can also override #CGI.SERVER_SOFTWARE#, #CGI.PATH_INFO#, #CGI.WEB_SERVER_API#, and many others
- Be particularly careful with #CGI.AUTH_USER#

Persistence Issues

- Client scope variables can be configured in Application.cfm in the CFAPPLICATION tag (attribute “clientmanagement”) or this.clientmanagement in Application.cfc
 - Keyed to browser via CFTOKEN/CFID cookies; actual variable storage may be client-side (other cookies) or server-side (in a database or the Windows registry)
 - All of these cookies persist by default, so watch for cookie theft/stuffing attacks
- When client scope is enabled, tampering is possible if cookie storage is enabled (“clientStorage” attribute/variable)
e.g. `<cfapplication clientManagement="yes" clientStorage="Cookie">`
 - No encryption or MAC; everything is in plain text

ColdFusion Behind the Curtain

Proprietary Classfile Format

- CF can compile pages/components to sets of Java classes using the cfcompile utility
- One class per page plus one for every UDF
- All class generated for a single CFM/CFC file are placed in one file, concatenated; a custom ClassLoader is used by CF to load them up
- Names of the resulting concatenated files are identical to those of the source files
- Separately, ColdFusion Administrator can be used to bundle a directory as an EAR/WAR

A Way to Slice Them: cfexplode

- Free, open-source Java utility written by Brandon Creighton at Veracode, available from Google Code:
<http://code.google.com/p/cfexplode/>
- Splits concatenated classfiles into many; can accept individual compiled CFC/CFM files or full WAR/EAR/JAR zip archives

```
% java -jar cfexplode.jar outdir index.cfm
% ls -l outdir
total 40
-rw-r--r-- 1 cstone cstone 3534 2010-07-16 15:23 index.cfm.0.class
-rw-r--r-- 1 cstone cstone 2095 2010-07-16 15:23 index.cfm.3534.class
-rw-r--r-- 1 cstone cstone 31234 2010-07-16 15:23 index.cfm.5629.class
```

- Individual classes easily analyzable (even with the free JAD and JD-GUI)

Page/Component/Function Java Classes

- CFM/CFC: main point of entry is CFPage.runPage()
 - Other methods called beforehand set up data: variable bindings (bindPageVariables()), function names (registerUDFs()), data sources
- <cffunction>: main point of entry is UDFMethod.runFunction()
 - Argument validation is done by the runtime; any types specified in <cfargument> tags are translated into a static Map instance named “metaData”
- CfJspPage (base class).pageContext is a plain old JspContext, so pageContext.getOut() returns a JspWriter; this is used to do the bulk of the output
 - getOut() also used for things that aren't actually output to the screen, such as database queries
- Occasionally, parts of the body are factored out of runPage into separate private methods named factor0(), factor1(), factor2()..

CF Variables in Java: Static References

- Static references, usually used for local bindings

```
<cfset vfoo="value 1">
<cfparam name="pbar"
    default="value2">
<html>
    <cfoutput>
        vfoo: #vfoo#    pbar: #pbar#
    </cfoutput>
</html>
```

- When compiled:

```
protected final Object runPage()
{
    // ...
    VF00.set("value 1");
    _whitespace(out, "\n");
    checkSimpleParameter(PBAR,
"value2");
    out.write("\n\n<html>\n    ");
    // ...
    out.write("\n        vfoo: ");
    out.write(Cast._String(
_autoscalarize(VF00)));
    out.write("    pbar: ");
    out.write(Cast._String(
_autoscalarize(PBAR)));
    _whitespace(out, "\n    ");
    // ...
}
```

CF Variables in Java: Dynamic References

- Dynamic references, explicitly-scoped variables

```
<html>
<cfoutput>
  #url.quux#
</cfoutput>
</html>
```

- When compiled:

```
protected final Object runPage()
{
  // ...
  out.write("<html>\n    ");
  _whitespace(out, "\n        ");
  out.write(Cast._String(
      _resolveAndAutoscalarize("URL", _new String[] { "QUUX" })))
  );
  // ...
}
```

WAR/Application Structure

- CFMs/CFCs handled by different Servlets (CfmServlet and CFCServlet, respectively)
- These locate the class(es) necessary based on URL and parameters, then invoke their runPage()/runFunction() methods
- Chain of coldfusion.filter.FusionFilter classes (not related to J2EE Servlet filters); these handle client-scope propagation
- Even if the “Include CF Administrator” option is unchecked, many pages/components inside the CFIDE/ directory are included inside every WAR
 - Mapped by default
 - Access may not be password-protected; easily disabled by a change to neo-security.xml (see <http://kb2.adobe.com/cps/404/404799.html>)

WAR Structure: Other Servlets

- *.jsp: JSPLicenseServlet; passthrough for jrun.jsp.JPSServlet
- /flex2gateway/*, /flashservices/gateway/*, /CFFormGateway/*: FLEX/plain Flash Remoting gateways for CFC methods
 - /flashservices/gateway/path1.path2.component ⇒ path1/path2/component.cfc
 - Gateways can be used in ActionScript NetServices.createGatewayConnection()
 - Used internally by <cfgrid> and other built-in cf tags that generate Flash-based UI automatically
- GraphServlet: handles /CFIDE/GraphData.cfm (not actually a cfm file); used by the cfchart tag.
- CFFileServlet: handles /CFFileServlet/*, and serves up files from a cache directory; used by <cfimage>
- /cfform-internal/*: FLEX FileManagerServlet; serves a handful of dynamically-generated images and js files
- /WSRPPProducer/*: WSRP portlet management Axis service

Final Thoughts

Conclusions

- ColdFusion designed to be simple for “developers” to use, but it’s actually very complicated underneath
- It’s easy to make coding mistakes (or overlook vulnerabilities during code review) if you don’t understand ColdFusion internals
 - Request lifecycle
 - Error handling
 - Variable scopes and precedence
- Like many web application platforms, ColdFusion has a bunch of “features” that are useful for debugging but also open up holes
- ColdFusion-generated Java classes are pretty ugly; use **cfexplode** to help reverse engineer them
- The attack surface is huge by default; strip out unnecessary components before deploying

More Resources

- Whitepapers, webcasts, and other educational resources
 - <http://veracode.com/resources>
- Veracode ZeroDay Labs Blog
 - <http://veracode.com/blog>
- Download the cfexplode tool
 - <http://code.google.com/p/cfexplode/>
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